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REPORT

ON

1863

THE APPLICATION OF

GUN-COTTON TO WARLIKE PURPOSES.

BY A COMMITTEE

CONSISTING OF

J. H. Gladstone, Ph.D., F.R.S., Prof. W. A. Miller, M.D., F.R.S., and Prof. E. Frankland, Ph.D., F.R.S., from Section B.; and W. Fairbairn, LL.D., F.R.S., Joseph Whitworth, F.R.S., James Nasmyth, C.E., F.R.A.S., J. Scott Russell, C.E., F.R.S., John Anderson, C.E., and Sir W. G. Armstrong, C.B., LL.D., F.R.S., from Section G.

[*From the* Report *of the* British Association *for the* Advancement *of* Science *for* 1863.]

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1863.

J. F. Campbell Esq^re.
with J H Gladstone's kind regd^s.

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REPORT

ON

GUN-COTTON.

Report on the Application of Gun-cotton to Warlike purposes. By a Committee, consisting of J. H. GLADSTONE, *Ph.D., F.R.S.,* Prof. W. A. MILLER, *M.D., F.R.S., and* Prof. E. FRANKLAND, *Ph.D., F.R.S., from Section B.; and* W. FAIRBAIRN, *LL.D., F.R.S.,* JOSEPH WHITWORTH, *F.R.S.,* JAMES NASMYTH, *C.E., F.R.A.S.,* J. SCOTT RUSSELL, *C.E., F.R.S.,* JOHN ANDERSON, *C.E., and* Sir W. G. ARMSTRONG, *C.B., LL.D., F.R.S., from Section G.*

SINCE the invention of gun-cotton by Professor Schönbein of Basle, the thoughts of many have been directed to its application to warlike purposes. Many trials and experiments have been made, especially by the French Government; but such serious difficulties and objections presented themselves, that the idea seemed to be abandoned in every country but one. That country was Austria. From time to time accounts reached England of its partial adoption in the Austrian service—though no explanation was afforded of the mode in which the difficulties had been overcome, or the extent to which these attempts had been successful.

This was the state of the case when the present Committee was appointed.

During the year your Committee have been put in possession of the fullest information on the subject, mainly from two sources, F. A. Abel, Esq., F.R.S., the Chemist to the War Department, and Baron William von Lenk, Major-General of the Austrian Artillery, who is the inventor of the system by which gun-cotton is made practically available for warlike purposes.

Mr. Abel, by permission of the Secretary of State for War, has communicated the information given by the Austrian Government to the Government of this country, and the results which he has himself arrived at during the course of an elaborate series of experiments.

General von Lenk, on the invitation of your Committee, and by permission of the Emperor of Austria, paid a visit to this country, with the object of answering any inquiries the Committee might make, and explaining his system thoroughly; and for this purpose he brought over drawings and samples from the Imperial factory.

In addition to these principal sources of information, your Committee would mention the services rendered by two of their own number. Prof. Frankland was able to corroborate by his own experiments most of the statements made in the earlier communications of Mr. Abel. Mr. Whitworth has made experiments on the application of gun-cotton in mines, and has sent over to Austria rifles and ammunition, to be experimented with by Baron von Lenk, with a view of obtaining results, which he has promised to communicate to the Committee.

The following documents form part of this Report, and contain the information received.

I. Report by Mr. Abel, received February 1863, on the system of manufacture of gun-cotton, as carried on in the Imperial Austrian Establishment.

II. Report by Mr. Abel, dated February 20th, 1863, on the composition, and some properties, of specimens of gun-cotton prepared at the Austrian Government Works.

III. Memorandum by Mr. Abel, with reference to experiments in progress bearing upon the manufacture of gun-cotton. Received August 27th, 1863.

IV. General von Lenk's replies to the questions put to him at the Meetings of June 22 and July 14.

V. Extracts from a report on Baron Lenk's gun-cotton by Profs. Redtenbacher, Schrötter, and Schneider. Dated June 1863.

On the data afforded by these documents, and other information communicated personally by Baron Lenk, your Committee have founded their present Report. It must therefore be regarded in the light of a preliminary inquiry. Should the Committee be reappointed, they will be happy to undertake some experiments with the view of clearing up those points which are still more or less obscure.

These communications are broken into paragraphs, which are numbered for convenience of reference; those of Mr. Abel are indicated by the letter A, those of Baron Lenk are distinguished by the letter L, whilst the extracts from the Austrian chemists are marked C.

The following is a summary of the more important matters referred to in this evidence, with the main conclusions which your Committee have drawn from them. The subject may naturally be divided into two parts, the chemical and the mechanical.

1. *Chemical Considerations.*

Under this head are included the manufacture of the gun-cotton itself, and the answers to such inquiries as those which refer to its liability, or non-liability, to deterioration by keeping, the possibility of its spontaneous decomposition, and the nature and effects of the products into which it is resolved on explosion.

As to the chemical nature of the material itself, Baron Lenk's gun-cotton differs from the gun-cotton generally made, in its complete conversion into a uniform chemical compound. It is well known to chemists that, when cotton is treated with mixtures of strong nitric and sulphuric acids, compounds may be obtained varying considerably in composition, though they all contain the elements of the nitric acid, and are all explosive. The most complete combination, or product of substitution, is that described by Mr. Hadow as $C_{36}H_{21}(9NO_4)O_{30}$, which is identical with that termed by the Austrian chemists Trinitrocellulose, $C_{12}H_7(3NO_4)O_{10}$. (C. 2.) This is of no use whatever for making collodion, but it is Baron Lenk's gun-cotton, and he secures its production by several precautions. Of these the most important are—

1st. The cleansing and perfect desiccation of the cotton, as a preliminary to its immersion in the acids.

2nd. The employment of the strongest acids attainable in commerce.

3rd. The steeping of the cotton in a fresh strong mixture of acids, after its first immersion and partial conversion into gun-cotton.

4th. The continuance of the steeping for forty-eight hours.

5th. The thorough purification of the gun-cotton so produced, from every trace of free acid. This is secured by its being washed in a stream of water for several weeks. Subsequently a weak solution of potash may be used, but this is not essential.

The prolonged continuance of these processes appears at first sight superfluous, but it is really essential; for each cotton-fibre is a long narrow tube, often twisted and even doubled up, and the acid has first to penetrate into the very furthest depths of these tubes, and afterwards has to be soaked out of them. Hence the necessity of time. It seems to have been mainly from want of these precautions that the gun-cotton experimented on by the French Commission gave irregular and unsatisfactory results. (C. 1.)

From the evidence before the Committee, it appears that this highest nitro-compound, when thoroughly free from acid, is not liable to some of the objections which have been urged against that mixture of compounds which has been usually employed for experiments on gun-cotton.

These advantages may be classed as follows:—

1st. It is of uniform composition, and thus the force of the gases generated on explosion may be accurately estimated. (C. 2.)

2nd. It will not ignite till raised to a temperature of at least 136° C. (277° F.), a heat which does not occur unless artificially produced by means which would render gunpowder itself liable to ignition. (C. 5.)

3rd. It is almost absolutely free from ash when exploded in a confined space.

4th. It has a very marked superiority in stability over other forms of gun-cotton. It has been kept unaltered for fifteen years, and is not liable to that spontaneous slow decomposition which is known to render lower products worthless after a short time. (C. 4, 6.) Yet there are still some reasons for suspecting that even the gun-cotton produced at the Imperial works suffers some gradual deterioration, especially when exposed to the sunlight. (A. 20, C. 3.)

The details of the process of manufacture at Hirtenberg are given at length in Mr. Abel's first report, in General von Lenk's replies (L. 21), and in a patent (No. 1090) taken out by Mr. Thomas Wood Gray, and sealed Oct. 10, 1862.

The course of proceeding recently adopted at the Royal Gunpowder Works, Waltham Abbey, is fully described in Mr. Abel's third memorandum. (A. 10–16.)

There is one part of the process not yet alluded to, and the value of which is more open to doubt, namely, the treatment of the gun-cotton with a solution of silicate of potash, commonly called water-glass. Mr. Abel (A. 15) and the Austrian chemists think lightly of it; but Baron Lenk considers that the amount of silica set free on the cotton by the carbonic acid of the atmosphere is really of service in retarding the combustion. He adds that some of the gun-cotton made at the Austrian Imperial Works has not been silicated at all, and some but imperfectly; but when the process has been thoroughly performed, he finds that the gun-cotton has increased permanently about 3 per cent. in weight. A piece of one of the samples left by the

General was indeed found to contain 2·33 per cent. of mineral matter, consisting chiefly of silica*.

Much apprehension has been felt about the effect of the gases produced by the explosion of gun-cotton. It has been stated that both nitrous fumes and prussic acid are among these gases, and that the one would corrode the gun, and the other poison the artillerymen. Now, though it is true that from some kinds of gun-cotton, or by some methods of decomposition, one or both of these gases may be produced, the results of the explosion of the Austrian gun-cotton, without access of air, are found by Karolyi to contain neither of these, but to consist of nitrogen, carbonic acid, carbonic oxide, water, and a little hydrogen, and light carburetted hydrogen. (C. 7.) These are comparatively innocuous; and it is distinctly in evidence that practically the gun is less injured by repeated charges of gun-cotton than of gunpowder, and that the men in casemates suffer less from its fumes. (L. 13.) The importance of this latter property in a fortress, or a ship, will be at once apparent.

It seems a disadvantage of this material as compared with gunpowder that it explodes at a lower temperature, possibly at 136° C (277° F.); but against the greater liability to accident arising from this cause may be set the greatly diminished risk of explosion during the process of manufacture, since the gun-cotton is always immersed in liquid, except in the final drying; and that may be performed, if desirable, at the ordinary temperature of the air. Again, if it should be considered advisable at any time, it may be stored in water, and only dried in small quantities when required for use.

The fact that gun-cotton is not injured by damp like gunpowder, is indeed one of its recommendations. It is not even so liable to absorb moisture from the atmosphere, 2 per cent. being the usual amount of hygroscopic moisture found in it; and should that quantity be increased through any extraordinary conditions of the air, the gun-cotton speedily parts with its excess of moisture when the air returns to its ordinary state of dryness. (A. 5 & 8.)

But a still more important chemical advantage which gun-cotton possesses, arises from its being perfectly resolved into gases on explosion, so that there is no smoke to obscure the sight of the soldier who is firing, or to point out his position to the enemy; and no residue left in the gun to be got rid of before another charge can be introduced.

2. *Mechanical Considerations.*

At the outset of this inquiry the Mechanical Members of the Committee found it difficult to believe that greater effects are produced by a given volume of gases generated from gun-cotton than by an equal volume of gases generated from gunpowder; nevertheless, from the facts as brought before the Committee, such contradiction would at first sight appear to exist.

The great waste of force in gunpowder constitutes an important difference between it and gun-cotton, in which there is no waste. According to the experiments of Bunsen and Schischkoff†, the waste in gunpowder is 68 per cent. of its own weight, and only 32 per cent. is useful. This 68 per cent. is not only waste in itself, but it wastes the power of the remaining 32 per cent. It wastes it mechanically, by using up a large portion of the mechanical force of the useful gases. The waste of gunpowder issues from the gun with much higher velocity than the projectile; and if it be remembered that in 100 lbs. of useful gunpowder this is 68 lbs., it will appear that a portion of the 32 lbs. of useful gunpowder gas must be employed in impelling a 68 lb. shot composed of the refuse of gunpowder itself.

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* Two combustions of it, made by Dr. Gladstone, gave respectively 2·27 and 2·4 per cent. of ash. It was mainly insoluble silica in a state of very fine division, but acids dissolved out of it an appreciable amount of lime.

† Pogg. Annal. 4th Series, vol. xii. p. 131.

There is yet another peculiar feature of gun-cotton: it can be exploded in any quantity instantaneously. This was once considered its great fault; but it was only a fault when we were ignorant of the means to make that velocity anything we pleased. General von Lenk has discovered the means of giving gun-cotton any velocity of explosion that is required, by merely varying the mechanical arrangements under which it is used. Gun-cotton in his hands has any speed of explosion, from 1 foot per second to 1 foot in $\frac{1}{1000}$ of a second, or to instantaneity. The instantaneous explosion of a large quantity of gun-cotton is made use of when it is required to produce destructive effects on the surrounding material. The slow combustion is made use of when it is required to produce manageable power, as in the case of gunnery. It is plain, therefore, that if we can explode a large mass instantaneously, we get out of the gases so exploded the greatest possible power, because all the gas is generated before motion commences, and this is the condition of maximum effect. It is found that the condition necessary to produce instantaneous and complete explosion is the absolute perfection of closeness of the chamber containing the gun-cotton. The reason of this is, that the first ignited gases must penetrate the whole mass of the cotton; and this they do (and create complete ignition throughout) only under pressure. This pressure need not be great. For example, a barrel-load of gun-cotton will produce little effect and very slow combustion when out of the barrel, but instantaneous and powerful explosion when shut up within it.

On the other hand, if we desire gun-cotton to produce mechanical work and not destruction of materials, we must provide for its slower combustion. It must be distributed and opened out mechanically, so as to occupy a larger space, and in this state it can be made to act even more slowly than gunpowder; and the exact limit for purposes of artillery General von Lenk has found by critical experiments. In general it is found that the proportion of 11 lbs. of gun-cotton, occupying 1 cubic foot of space, produces a greater force than gunpowder (of which from 50 to 60 lbs. occupy the same space), and a force of the nature required for ordinary artillery. But each gun and each kind of projectile requires a certain density of cartridge. Practically gun-cotton is most effective in guns when used as $\frac{1}{4}$ to $\frac{1}{3}$ weight of powder, and occupying a space of $1\frac{1}{10}$th of the length of the powder cartridge, and of such density that 11 lbs. occupy a cubic foot.

The mechanical structure of the cartridge is of high importance, as affecting its ignition. The cartridge is formed of a mechanical arrangement of spun cords; and the distribution of these, the place and manner of ignition, the form and proportion of the cartridge, all affect the time of complete ignition. (A. 19. L. 22.) It is by the complete mastery he has gained over all these minute points that General Lenk is enabled to give to the action of gun-cotton on the projectile any law of force he pleases.

Even at the present high price of cotton, its cost of production is said to be less than that of gunpowder, the price of quantities being compared which will produce equal effects. (L. 20.)

Practical Applications.

Gun-cotton is used for artillery in the form of thread or spun yarn. In this simple form it will conduct combustion slowly in the open air at a rate of not more than 1 foot per second. This thread is woven into a texture or circular web. These webs are made of various diameters; and it is out of these webs that common rifle cartridges are made, merely by cutting them into the proper lengths, and enclosing them in stiff cylinders of pasteboard, which form the cartridge. In this shape its combustion in the open air takes place at a speed of 10 feet per second. In these cylindrical webs it is also used to fill explosive shells, as it can be conveniently employed in this shape to pass in through the neck of the shell. Gun-cotton thread is spun into ropes in the usual way, up to 2 inches diameter, hollow in the centre. This is the form used for blasting and mining purposes; it combines great density with speedy explosion, and in this form it is conveniently coiled in casks and stowed in boxes. The gun-cotton yarn is used directly to form cartridges for large guns, by being wound round a bobbin, so as to form a spindle like that used in spinning-mills. The bobbin is a hollow tube of paper or wood. The object of the wooden rod is to secure in all cases the necessary length of chamber in the gun required for the most effective explosion. The gun-cotton circular web is enclosed in tubes of india-rubber cloth to form a match-line, in which form it is most convenient, and travels with speed and certainty.

Conveyance and storage of gun-cotton.—It results from the foregoing facts that 1 lb. of gun-cotton produces the effect of more than 3 lbs. of gunpowder in artillery. This is a material advantage, whether it be carried by men, by horses, or in waggons. It may be placed in store and preserved with great safety. (L. 7, & 16.) The danger from explosion does not arise until it is confined, as it simply burns intensely in the open air. It may become damp, and even perfectly wet without injury, and may be dried by mere exposure to the air. This is of great value in ships of war; and in case of danger from fire, the magazine may be submerged without injury.

Practical use in artillery.—It is easy to gather from the foregoing general facts how gun-cotton keeps the gun clean, and requires less windage, and therefore performs much better in continuous firing. In gunpowder there is 68 per cent. of refuse, or the matter of fouling. In gun-cotton there is no residuum, and therefore no fouling.

Experiments made by the Austrian Committee proved that 100 rounds could be fired with gun-cotton against 30 rounds of gunpowder.

In firing ordnance with gun-cotton, the gun does not heat to any important extent. Experiments showed that 100 rounds were fired with a 6-pounder in 34 minutes, and the gun was raised by gun-cotton to only 122° Fahrenheit, whilst 100 rounds with gunpowder took 100 minutes, and raised the temperature to such a degree that water was instantly evaporated. The firing with the gunpowder was therefore discontinued; but the rapid firing with the gun-cotton was continued up to 180 rounds without any inconvenience. (L. 9.) The absence of fouling allows all the mechanism of a gun to have more exactness than where allowance is made for fouling. The absence of smoke promotes rapid firing and exact aim.

The fact of smaller recoil from a gun charged with gun-cotton is established by direct experiment; its value is two-thirds of the recoil from gunpowder —the projectile effect being equal. (L. 5.) To understand this may not be easy. The waste of the solids of gunpowder accounts for one part of the saving, as in 100 lbs. of gunpowder 68 lbs. have to be projected in addition to the shot, and at much higher speed. The remainder General von Lenk attributes to the different law of combustion; but the fact is established.

The comparative advantage of gun-cotton and gunpowder for producing high velocities is shown in the following experiment with a Krupp's cast steel gun, 6-pounder. An ordinary charge, 30 ounces powder, produced 1338 feet per second. A charge of 13½ oz. gun-cotton produced 1563 feet.

The comparative advantage in shortness of gun is shown in the following experiments with a 12-pounder:—

	Charge.	Length of gun.	Velocity.
Gunpowder	49·0 oz.*	13½ calibres.	1400
Gun-cotton	15·9 ,,	10 ,,	1426
,, ...	17·0 ,,	9 ,,	1402

Advantage in weight of gun.—The fact of the recoil being less, in the ratio of 2 : 3, enables a less weight of gun to be employed as well as a shorter gun, without the disadvantage to practice arising from lightness of gun. (L. 5.)

Endurance of gun.—Bronze and cast iron guns have been fired 1000 rounds without in the least affecting the endurance of the gun.

Application to destructive explosions. Explosion of Shells.—From some unexplained difference in the action of gun-cotton, there is an extraordinary difference of result as compared with gunpowder; namely, the same shell is exploded by the same quantity of gas into more than double the number of pieces. This is partly to be accounted for by the greater velocity of explosion when the gun-cotton is confined very closely in very small spaces. It is also a peculiarity, that the stronger the shell the smaller the fragments into which it is broken. (L. 17.)

Mining uses.—The fact that the action of gun-cotton is violent and rapid in exact proportion to the resistance it encounters, tells us the secret of its far higher efficacy in mining than gunpowder. The stronger the rock the less gun-cotton comparatively with gunpowder is necessary for the effect; so much so that, while gun-cotton is stronger than powder as 3 to 1 in artillery, it is stronger in the proportion of 6·274 : 1 in a strong and solid rock, weight for weight. It is the hollow rope form which is used for blasting. Its power of splitting up the material can be regulated at will.

Against the gates of a city.—It is a well-known fact that a bag of gunpowder nailed on the gates of a city will blow them open. In this case gun-cotton would fail; a bag of gun-cotton exploded in the same way is powerless. If 1 ounce of gunpowder is exploded in scales the balance is thrown down; with an equal force of gun-cotton the scale-pan is not depressed. To blow up the gates of a city, a very few pounds of gun-cotton carried in the hand of a single man will be sufficient; only he must know its nature. In a bag it is harmless; exploded in a box it will shatter the gates to atoms.

Against the palisades of a fortification.—A small square box containing 25 lbs. merely flung down close to them, will open a passage for troops. In an actual experiment on palisades a foot diameter and 8 feet high, driven 3 feet into the ground, backed by a second row of 8 inches diameter, a box of 25 lbs. cut a clean opening 9 feet wide. On this three times the weight of gunpowder produced no effect whatever, except to blacken the piles.

Against bridges.—A strong bridge of oak, 12 inches scantling, 24 feet span, was shattered to atoms by a small box of 25 lbs. laid on its centre: the bridge was not broken, it was shivered.

Under water.—Two tiers of piles 10 inches thick, in water 13 feet deep, with stones between them, were blown up by a barrel of 100 lbs. gun-cotton placed 3 feet from the face, and 8 feet under water. It made a clean sweep through a radius of 15 feet, and raised the water 200 feet. In Venice, a barrel of 400 lbs. placed near a sloop in 10 feet water at 18 feet distance, shattered it to pieces and threw the fragments to a height of 400 feet.

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* Ordinary charge of powder.

All experiments made by the Austrian Artillery Committee were conducted on a grand scale—36 batteries of 6- and 12-pounders having been constructed for gun-cotton, and practised with that material. The reports of the Commissioners are all based on trials with ordnance from 6-pounders to 48-pounders smooth-bore and rifled cannon. The trials with small fire-arms have been comparatively few, and are not reported on. The trials for blasting and mining purposes were also made on a large scale by the Imperial Engineers Committee, and several reports have been made on the subject.

The Committee desire to put upon record their conviction that the subject has neither chemically nor mechanically received the thorough investigation which it deserves. There remain many exact measures still to be made, and many important data to be obtained. The phenomena attending the explosion of both gun-cotton and gunpowder have to be investigated, both as to the temperatures generated in the act of explosion, and the nature of the compounds which result from them under circumstances strictly analogous to those which occur in artillery practice; and until these are accurately ascertained, it is impossible to reconcile the apparent contradictions between the mechanical phenomena which result from the employment of gun-cotton gases and gunpowder gases, when employed to do the same kind of mechanical work.

APPENDIX.

I.—*System of Manufacture of Gun-cotton as carried on in the Imperial Austrian Establishment.* *By* F. A. Abel, *F.R.S.*

(1) The cotton employed is of superior quality, tolerably free from seed; it is carded loosely, twisted, and made up into skeins before conversion. The strands of the cotton composing the skeins are of two sizes—the larger being intended for cannon-cartridges, and the other for small-arm cartridges and bursters.

(2) *Preparatory Preparation of the Cotton.*—The cotton, made up into skeins weighing about 3 ounces each, is washed in a solution of pure carbonate of potassa of the specific gravity 1·02, being immersed in the boiling solution for a short time. Upon removal from the alkaline liquid, the skeins are placed in a centrifugal machine, by which the greater portion of the liquid is separated. The skeins are now washed in clear running water, either by allowing them to remain in it for three or four hours, or else by washing each skein by hand for a few minutes. They are then again worked in a centrifugal machine and afterwards dried—in summer by the rays of the sun, but during winter in a drying-house heated by air-pipes to between 30° and 38° C.; the latter plan usually takes four or five days.

(3) *Production of the Gun-cotton.*—The nitric acid employed has a spec. grav. of 1·53, and the sulphuric acid a spec. grav. of 1·82. They are mixed in the proportion of three parts by weight of sulphuric acid and one part of nitric acid.

Two skeins (about 6 ounces) of the cotton are immersed at one time in the mixed acids, and moved about for a few moments with iron paddles. They are then raised upon a grating above the level of the acids and submitted to gentle pressure; thence they are transferred to covered stone jars, each of which receives six skeins of known weight. The jars are then weighed, some of the mixed acids being added if necessary, to bring the proportion of acids up to $10\frac{1}{2}$ lbs. to 1 lb. of cotton.

The jars are set aside for forty-eight hours in a cool place; in summer they should be placed in cold water. When that period has elapsed, the acid is separated from the cotton as far as possible by means of a centrifugal machine, as before described. The men working the machine are protected from the fumes of the acids by a wooden partition. The acids removed from the cotton are not used again in the preparation of gun-cotton.

The skeins of gun-cotton are at once removed from the centrifugal machine to perforated receptacles, which are immersed in a stream, where they are allowed to remain at least three weeks. Each skein is afterwards separately rinsed in the stream to remove mechanical impurities, and the water is then separated by the centrifugal machine.

The gun-cotton is next submitted to treatment with a solution of carbonate of potassa, as in the preliminary process, and again washed after the alkaline liquid has been expressed. When the skeins have been allowed to dry tolerably by simple exposure to air, they are placed in a large wooden tub containing a solution of silicate of soda, the temperature of which is about 15° C. This solution should have a specific gravity of 1·072, and is prepared as required from a solution of spec. grav. 1·216. The cotton remains one hour in the solution of silicate of soda, which is supposed to exercise two functions:—

(*a*) That of protecting the cotton by acting as a varnish upon the fibres.

(*b*) That of retarding its combustion.

Upon removal of the gun-cotton from the bath of water-glass, the liquid is partly expressed by hand, and afterwards more fully by means of the centrifugal machine. The skeins must then be thoroughly dried. They are afterwards immersed in running water for five or six hours, and each skein subsequently washed by hand. The water having been extracted by the centrifugal machine, the gun-cotton is removed to the drying-house, where it remains eight or ten days. Its manufacture is then completed.

The gun-cotton is packed in ordinary deal boxes lined with paper, and kept in dry magazines until required to be made into cartridges, &c.

Well-organized arrangements are employed for mixing the sulphuric and nitric acids, immersing the cotton, and for conducting the various other operations connected with the manufacture.

II.—*On the Composition, and some Properties, of Specimens of Gun-cotton prepared at the Austrian Government Works.* *By* F. A. Abel, *F.R.S.*

(4) Several specimens of gun-cotton prepared at the Imperial Factory at Hirtenberg near Vienna*, being the descriptions manufactured for cannon, for shells, and for small arms, were submitted to chemical examination, to determine the following points:—

(*a*) The proportion of hygroscopic moisture existing in them, under normal conditions.

(*b*) The composition of the different specimens of gun-cotton.

(*c*) The proportion and nature of their mineral constituents.

(5) I. The proportion of moisture expelled from the samples of gun-cotton,

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* Several of these specimens were taken from ammunition, &c., which were being used at the time, for experimental practice, by the Austrian authorities.

by exposure to desiccation *in vacuo* over sulphuric acid, was very uniform. The specimens were examined both in the condition in which they were found on opening the parcel containing them, and after their exposure for some time to a temperate and moderately dry atmosphere. The mean proportion of hygroscopic moisture found in the gun-cotton was 2 per cent. Further experiments, relating to the hygroscopic properties of the gun-cotton, will be described hereafter.

(6) II. The composition of the specimens of Austrian gun-cotton, *i. e.* the proportion of hydrogen-atoms which had been replaced, in the original cotton, by hyponitric acid, was determined by the synthetical method first employed by Mr. Hadow, in his examination of the substitution-products obtained by the action of nitric acid upon cotton*. The dried specimens of gun-cotton were digested in the cold, for twenty-four hours, in an alcoholic solution of sulphhydride of potassium (KS, HS), prepared as described by Mr. Hadow; and the reduced cotton thus obtained in each case was thoroughly washed and dried. These products, after weighing, were proved to be free from nitrogen-compounds, by the ignition of portions with hydrate of potassa, when no indications of the existence of nitrogen in the specimens were obtained.

The percentage of cotton obtained by this synthetical method from four specimens of the gun-cotton were as follows:—

I. 55·20 per cent.
II. 55·07 per cent.
III. 55·13 per cent.
IV. 54·97 per cent.

These results show, as might have been predicted from the method of treatment of the cotton adopted, that the products obtained at the Austrian works consist, very uniformly, of the most highly explosive variety of gun-cotton, represented by the formula $C_{36}\,H_{21}\,O_{30},\ 9\ NO_4$, as is shown by a comparison of the above numbers with Mr. Hadow's results, and with the theoretical percentage number:—

By synthesis.		By analysis. Hadow.		By calculation.
Cotton found in Austrian samples.	Hadow.			
55·20				
55·07	55·13	54·6	55·19	54·54
55·13				
54·97				

(7) III. The proportions of non-volatile matter or ash contained in the specimens of gun-cotton were determined in the following manner. The weighed gun-cotton was thoroughly moistened with distilled water; it was then cut into small fragments, and these were projected from time to time into a deep platinum vessel heated to dull redness. In this manner the gun-cotton was decomposed very gradually, the expulsion of the volatile portions being placed under such complete control as to exclude the possibility of any mechanical dispersion of portions of the ash. The heat was finally raised sufficiently to burn off any small quantity of residual carbon. From the ash thus obtained, the proportion was calculated upon the dry gun-cotton. Results obtained by this method from several determinations, with the same

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* Quart. Journ. Chem. Society, vol. vii. p. 201.

specimen of gun-cotton, were closely concordant; but those furnished by different specimens varied slightly.

The following were the mean percentage results obtained:—

	Per cent.
(*a*) From a specimen of gun-cotton prepared for cannon	1·14
(*b*) From a specimen of gun-cotton prepared for small arms and shells	0·42
(*c*) From a specimen of gun-cotton prepared for blasting-purposes	1·90

(This specimen was slightly discolored, made from a lower quality of cotton, and not so perfectly washed as (*a*) and (*b*).)

The analysis of the ash furnished by the gun-cotton in these experiments, demonstrated the existence of some differences in the proportions of the several mineral constituents of the different specimens. The ash from (*a*) consisted of

Silicic acid	0·71 per cent. in the cotton.
Lime	0·13 ,, ,,
Magnesia	trace
Oxide of iron......	trace
Alkalies	0·25 ,, ,,
Sulphuric acid	trace

That furnished by specimen (*b*) consisted principally of lime; it contained besides traces of magnesia, oxide of iron, and alkalies, and only a small trace of silicic acid.

The ash from (*c*) consisted of—

Sand and clay	0·75 per cent. in the cotton.
Silicic acid, soluble ..	0·53 ,, ,,
Lime	0·27 ,, ,,
Alkalies	0·30 ,, ,,
Magnesia .... Oxide of iron .... Sulphuric acid	traces.

The ash was determined for comparison in a specimen of cotton obtained from the Austrian Works, which had been submitted to the preparatory purifying processes (treatment with carbonate of potassa and long-continued washing). The results obtained furnished a mean of 0·63 per cent. of ash, which consisted principally of lime and magnesia, and contained a small proportion of insoluble matter (clay and sand), traces of soluble silicic acid, and of alkalies.

The above determinations and analyses of the ash in the gun-cotton and in the unconverted cotton, show that no result of the slightest practical importance, in the direction supposed to be aimed at, is obtained by the treatment with solution of soluble glass, to which the purified gun-cotton is submitted, according to the Austrian system of manufacture.

It is evident that, by the washing in running water for five or six hours, and subsequent rinsing of each skein, *after* the treatment with silicate of soda, the proportion of the latter which had in the first instance been introduced into the cotton is again extracted, only traces being retained by the cotton, besides a very small proportion of silica in the form of pulverulent silicate of lime, resulting from the decomposition of the soluble glass by the lime-salts in the spring- or river-water. It will be observed that, in specimen (*b*) of gun-cotton, the proportion of non-volatile constituents is actually even less than that found in the purified but unconverted cotton,—a fact which is evidently due to the solvent action of the acids upon portions of the mineral matter in the cotton. In the place of the comparatively large proportions of lime and magnesia in the *original* cotton, the product which, after separation from the acids by very long-continued washing, &c., has been submitted to treatment with soluble glass and again washed, contains some small quantities (necessarily variable in a product of manufacture) of impurities (clay and sand) derived from the water used, and of silicic acid in combination with lime and also with soda, minute quantities of the soluble glass having escaped removal or decomposition in the final washing process. Supposing that the maximum proportion of silicates (1 per cent.) found in the above determinations existed entirely in the form of soluble glass in the finished gun-cotton, a piece of twist 12 feet 10 inches in length, and of the size used for Artillery purposes ($\frac{1}{4}$ inch thick), would contain only one grain of soluble glass. It is evident therefore that no protective effect nor retardation in the explosion of the gun-cotton can result from the treatment with soluble glass to which it is submitted.

Experiments on the Hygroscopic Properties of the Austrian Gun-cotton.

(8) It has already been stated that the proportion of moisture contained, under normal conditions, in the specimens of Austrian gun-cotton was found to be very uniform, the mean proportion being fixed at 2 per cent. by the results of several experiments.

Some gun-cotton prepared from ordinary cotton-wool, and having the same composition as the Austrian samples—but not having been submitted to the preparatory or subsequent treatment with alkali, nor to the very long-continued washing—was examined with regard to its hygroscopic properties, in comparison with the Austrian gun-cotton. The proportion of moisture existing in the former, under ordinary conditions, was found to be almost identical with the average proportion in the Austrian samples.

Some experiments were instituted to ascertain the rate at which the Austrian gun-cotton would absorb moisture, on exposure to a damp atmosphere.

The specimens experimented with were first thoroughly dried *in vacuo* over sulphuric acid, and then exposed for successive periods, together with a shallow vessel containing water, under a capacious bell jar placed in a moderately warm room. The following results were obtained:—

Specimen.	Period of exposure to a damp atmosphere.					
	1 hr.	2 hrs.	4 hrs.	20 hrs.	30 hrs.	72 hrs.
No. 1	1·35	..	..	3·15	..	3·87
2	1·60	..	..	3·21	..	3·65
3	..	1·89	2·15	..	3·55	..
4	..	1·73	2·00	..	3·21	..
5	1·77	2·21	..	..	..	3·90

These results show that the rate of absorption of moisture by the gun-cotton is uniformly rapid up to the point where 2 per cent. (the normal proportion of hygroscopic moisture) have been absorbed, and that, when this point has been attained, the absorption of further moisture proceeds comparatively very slowly[*]. Several experiments were made to determine, as far as possible, the *maximum* amount of moisture which the gun-cotton would absorb from a damp confined atmosphere. The great rapidity with which the specimens operated upon parted with the water absorbed, on exposure to the ordinary atmosphere, after the experiments had been proceeded with for some days, rendered the attainment of accurate numbers very difficult. The results, however, showed very definitely that no important increase in the amount of water absorbed took place when it had reached from 5·5 to 6 per cent. When these specimens had ceased to absorb moisture, they were, after the last weighing, exposed to the atmosphere at the ordinary temperature for one hour, and again weighed, when they were found to have parted with very nearly one-half of the total proportion of water absorbed. After further exposure to air for about four hours, the proportion of moisture retained had fallen to the average normal percentage (2 per cent.), and afterwards evinced no further tendency to decrease.

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[*] Several determinations of the moisture in cotton rovings, both before and after treatment with alkali (and repeated washing), show that the proportion of hygroscopic moisture in the cotton amounts to between 6 and 7 per cent., this amount being reabsorbed by the dried cotton, within twenty-four hours, on exposure to air.

Two specimens were kept confined as described, together with a vessel of water, for several weeks in a moderately warm room. The water had then condensed, in numerous minute globules, upon the projecting filaments of the gun-cotton; the specimens were therefore very highly charged with moisture. In this condition they were exposed to the air at the ordinary temperature; within one hour and a half they contained only about 4·5 per cent. of moisture. After the lapse of a second similar period, the moisture had decreased to about 3 per cent. (3·16 in one specimen and 2·78 in the other). When again weighed, after a lapse of about four hours, the percentage of water had fallen, in both, to the average proportion.

Experiments corresponding to the above were made with the specimen of gun-cotton referred to above as having been prepared from common cotton-wool. The rate of absorption of moisture of this specimen was found to be decidedly more rapid than that of the Austrian gun-cotton; but they very closely resembled each other as regarded the rapidity with which they again parted, spontaneously, with the moisture absorbed from a damp atmosphere, and the average proportion ultimately retained. The differences noted in the rate of absorption of moisture between the two varieties of gun-cotton, is most probably due to the difference in their mechanical condition. Some of the specimens of Austrian gun-cotton used in these experiments were picked asunder, as loosely as possible, instead of being exposed in the form of twists; the difference thus established in the mechanical condition of the specimens did not affect, to any great extent, their relative hygroscopic properties. It was found impracticable, however, to reduce the gun-cotton rovings to the same mechanical condition as the gun-cotton prepared from finely carded wool.

It appears from the results above described, that—

(*a*) The proportion of moisture absorbed and retained, under ordinary circumstances, by the gun-cotton, is about double that contained under similar conditions in good gunpowder (which averages one per cent.).

(*b*) Gun-cotton possesses no tendency to absorb moisture beyond that proportion, unless in very damp situations; and even under those circumstances the proportion of moisture absorbed is limited. Moreover its capacity for retaining water (beyond the normal proportion) is so feeble that, however highly it may have accidentally become impregnated with moisture, it will return spontaneously to its original condition of dryness by simple exposure to the open air for a few hours. In these respects it possesses important advantages over gunpowder; for although the latter contains, under normal conditions, less moisture than gun-cotton, it exhibits great tendency to absorb water from a moist atmosphere, which it continues to exert until it actually becomes pasty. Moreover gunpowder, when once damp, cannot be restored to a serviceable condition without being again submitted to the incorporating and subsequent processes.

III.—*Memorandum with reference to Experiments in progress bearing upon the Manufacture of Gun-cotton. By* F. A. Abel, *F.R.S.* (*Received Aug.* 23, 1863).

Experiments of a preliminary character.

(9) The experiments on a manufacturing scale, instituted on the Austrian system of preparing gun-cotton for military purposes, were preceded by an examination into some of the regulations laid down for the treatment of the cotton—the objects of these preliminary experiments being partly the attainment of direct proof of the necessity of a strict adherence to certain details (relating to the strength of the nitric acid, the duration of the treatment of the cotton with the mixed acids, and the rejection of the mixture after being once used), and partly the acquirement of experience in the treatment of the cotton.

It was important, before proceeding with these experiments, to determine upon some method, both expeditious and trustworthy, for submitting the products of the numerous experimental preparations of gun-cotton to comparative examination with the highest substitution-product, *i. e.* the Austrian gun-cotton.

Mr. Hadow's synthetical method of examination, which had been successfully employed in determining the composition of the Austrian gun-cotton, though valuable for finally controlling the composition of any particular product, is not sufficiently expeditious for the particular object in view, *i. e.* the examination of small samples from products of manufacture before their entire bulk is submitted to the final (purifying) processes *.

The first method tried for submitting the products of manufacture to comparative examination was as follows:—The weighed gun-cotton was soaked in water, the excess being afterwards expressed; and it was then placed in a glass tube about 18 inches long and open at both ends. Into one extremity was fitted a delivery-tube, dipping into mercury or water; the other was connected with a gas-holder containing nitrogen; the communication between the latter and the tube could be cut off by means of a stopcock. Air was expelled from the tube by means of the nitrogen, and the wet gun-cotton was then heated as quickly as possible by an Argand flame, the tube being slightly inclined. The gun-cotton was rapidly decomposed, though not with explosive violence; the gases issuing from the tube were collected and measured. The volume of gas furnished by different specimens of the Austrian gun-cotton, and of several specimens of gun-cotton-twist prepared according to the prescribed method, were sufficiently uniform to furnish reliable comparative results; but the liability of the glass tube to fracture during the application of heat, by the water present, led to the abandonment of this method of proceeding in favour of the following more simple one. A capacious glass globe, fitted with a stopcock and copper wires passing to the interior, is attached to an air-pump, which is also in communication with the upper end of a barometric tube. A weighed quantity of the gun-cotton is wrapped round a platinum wire, stretching from one copper wire in the globe to the other. The globe, being again attached to the air-pump, is exhausted until the mercury in the tube stands at about 29 inches. The gun-cotton is then inflamed by the aid of a voltaic current, and the depression of the column of mercury is noted when the apparatus has thoroughly cooled. By this method, perfectly concordant indications were obtained in employing different specimens of the Austrian gun-cotton, and of products prepared according to the precise method for producing the most explosive gun-cotton, which had furnished proper results when examined synthetically *.

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* Many experiments were instituted with this method of examination, and it was found that although the results obtained corresponded closely to theoretical requirements, when the starting-point in the examination was the gun-cotton, results of similar precision were not furnished by it when the original cotton itself was taken as the starting-point. That is to say, in commencing with a known weight of dry cotton, submitting it to proper treatment with the mixed acids, washing the product as carefully as possible, so as to avoid mechanical loss, drying the pure gun-cotton, digesting it with sulphhydride of potassium solution, and proceeding, with all possible care, exactly according to the prescriptions given by Mr. Hadow, the reduced cotton is always somewhat lower in amount than the cotton originally employed, the deficiency varying within the limits of 1 per cent. This deficiency is unquestionably due to the abstraction, by the mixed acids, of portions of the mineral constituents and of small proportions of organic matter from the cotton, and also, to a slight extent, to mechanical loss in the washing operations, which it appears impossible to guard against altogether.

Experiments have been made with quantities of cotton-wool varying from one to two ounces, to ascertain how far the long-protracted contact (for forty-eight hours) of the cotton with the mixed acids, as prescribed in the Austrian system, is essential to the complete conversion of the cotton-wool into the most explosive gun-cotton. The products obtained by immersion of the cotton even for thirty minutes were found to be almost perfectly converted; the volumes of gas furnished by them and their synthetical examination showed, however, that they still probably contained small quantities of unconverted cotton. Continuous immersion for twenty-four hours was found in all cases to furnish products completely up to the theoretical standard. Considering that the quantity of cotton immersed in one quantity of acid in the actual process of manufacture is much more considerable than that with which these experiments could be made, and that it is in the form of skeins of a somewhat compact roving or yarn, it appears a safe and not unnecessary precaution, in order to ensure perfect uniformity, to submit the cotton to as long a period of immersion as that adopted in Austria.

A considerable increase in outlay being involved in the employment, on a manufacturing scale, of a nitric acid of any specific gravity higher than 1·5, comparative experiments have been made on the production of gun-cotton with acid of that specific gravity, and of the spec. grav. 1·52 prescribed in the Austrian system †, both acids being mixed with the proper proportion of strong sulphuric acid. In all the experiments, the resulting products were found to be identical in their nature. Considering therefore that, according to the directions laid down, the mixed acids are only to be employed for the treatment of one quantity of cotton, there appears to be no advantage derivable from the employment of nitric acid of a higher specific gravity than 1·5.

Several experiments have been instituted for the purpose of ascertaining whether the rejection of the acids as of no further value, after the immersion in them of one quantity of cotton, was likely to be indispensable to the production of uniform results. In one instance, four equal quantities of the same

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* In carrying on experiments to test the mode of examination, some interesting results were obtained bearing importantly upon the influence exerted over the rapidity and nature of decomposition of the gun-cotton by its position relatively to the source of heat, and by other variable conditions. These results have led to experiments now in progress.

† A sample of the nitric acid employed at Hirtenberg was collected on the spot; its specific gravity was found to be 1·515.

description of cotton were successively submitted for equal periods (forty-eight hours) to treatment with one and the same quantity of the mixed acids. The specific gravity of the latter, at the commencement of the experiment, was 1·82. The acid was separated from each quantity of the cotton at the expiration of the above period, by means of a small centrifugal machine. After two quantities of cotton had been immersed in the acid, its specific gravity was reduced to 1·81. The original mixed acids were examined by means of a standard solution of carbonate of soda; a known quantity of the mixture neutralized 148·3 measures of the solution. After immersion of the first quantity of cotton, 147·5 measures were neutralized by an equal quantity of the acid, and 146·3 measures after immersion of the second quantity of cotton. The reduction in the strength of the acid appeared therefore to be very uniform. The four products successively obtained were carefully purified and dried. The volumes of gas which they furnished upon ignition corresponded very closely with each other and with that obtained from a specimen of the Austrian gun-cotton.

In a second similar experiment, five different quantities of cotton were submitted successively to treatment for forty-eight hours with one and the same mixture of acids. The first three products furnished, upon comparative examination by the exploding method, almost identical results; the fourth and fifth afforded indications of less complete conversion. Examined synthetically, there was a difference of not quite 1 per cent. between the amount of recovered cotton obtained from the first and the fifth products.

The results of these experiments indicated, therefore, that products corresponding closely in composition can be obtained by the treatment of even more than two quantities of cotton successively with the same acid. It should be observed, however, that the above results were obtained with cotton in the unspun condition, and that the proportion borne by the mixed acids to the cotton was higher than that prescribed in the Austrian system of manufacture.

Experiments instituted upon a manufacturing scale at the Royal Gunpowder Works, Waltham Abbey.

(10) Very considerable difficulties were experienced in procuring the small quantity of cotton (two to three cwts.) required for these experiments, in a condition resembling sufficiently closely that employed at Hirtenberg, as its production in the form of the thick and the thin loose rovings, or yarn, necessitated some deviation from the ordinary method of spinning, which it was difficult to induce manufacturers to attempt without the promise of an extensive order. Eventually I succeeded, through the kind assistance of Mr. Whitworth, in obtaining the requisite quantity of coarse and fine yarn or roving, resembling closely in character, and quality of cotton, the specimens obtained from Hirtenberg, though in the subsequent operations with the coarse or thicker kind no inconsiderable proportion of it was found to be in a much less compact or more lightly twisted form than the Austrian samples. The comparatively open condition of this portion, and the impossibility of placing it under a sufficient strain to wind it compactly into cartridges, in consequence of the weakness of the yarn, must exert considerable influence upon the rapidity of its combustion in its employment in ordnance (as a few rough experiments at Waltham Abbey have indeed already shown); the gun-cotton prepared from these portions will therefore be carefully separated from the remainder, and will doubtless furnish instructive comparative re-

sults in the preliminary artillery experiments to be instituted with the gun-cotton.

The acids of the prescribed specific gravities were readily obtained at moderate prices—the sulphuric acid having a specific gravity of 1·84, and that of the nitric acid (a light amber-coloured acid) being 1·52.

The apparatus and implements employed, and the modes of conducting the various operations, were, as closely as practicable, in accordance with those in use at Hirtenberg—a slight deviation only, in the form or material of some of the implements, being adopted where it was decidedly advantageous and could not in any way influence the nature of the results. The following is an account of the details of manufacture:—

(11) a. *Preparation of the Cotton.*—The cotton was made up into skeins, those of the stout yarn weighing from four to six ounces each, and those of fine yarn from three to four ounces. It was then boiled for about fifteen minutes in a dilute solution of carbonate of potassa (of specific gravity 1·02, containing one pound of the salt to three gallons of water), and transferred thence to a centrifugal machine, which was maintained for about five minutes at a speed of 500 to 600 revolutions per minute. The alkaline liquid was thus very effectually separated from the cotton, which was then washed thoroughly, first by hand in a large tank, and afterwards by submersion in a stream for forty-eight hours. At the expiration of that period, the water was separated from the skeins by the aid of the centrifugal machine, and the purified cotton was then dried. Although the cotton was of good quality and very fairly cleaned from seed (being quite equal in these respects to the Austrian samples), it was found to sustain a loss of about 5 per cent. by the treatment with alkali and washing. The potassa solution in which it was boiled acquired a coffee colour. Portions of seed were still retained by the purified cotton, which were subsequently dissolved out perfectly by the acids.

(12) b. *Preparation of the Acids.*—The proportions of acids (three parts by weight, or 2·45 by volume, of sulphuric acid to one part of nitric acid) were weighed off and transferred to stoneware barrel-shaped vessels provided with taps, two of these receiving the sulphuric acid and a third the nitric acid. The barrels were so arranged upon a suitable table that the acids could be delivered from the taps into a deep and very capacious stoneware vessel, fitted with an iron lid with suitable apertures and a tap; this vessel was raised from the ground sufficiently to allow of the acids being transferred from it to well-stoppered stoneware bottles. While the acids were flowing slowly and uniformly from the barrels into the covered mixing-vessel, the resulting mixture was kept continuously stirred by means of a large iron paddle, and after they had been entirely transferred (which occupied about ten minutes), the stirring was continued for about twenty minutes before the mixture was drawn off into the bottles. The product of this operation had a specific gravity of 1·82. The elevation of temperature resulting from the mixture of the acids was considerable; in one observation the temperature of the acids before mixture was found to be 20° C., while that of the mixture, when complete, was 38° C. The acid thus prepared was set aside in a cool place, and never employed until at least twenty-four hours after the mixture had been made.

The mixing process and all the other operations with the acids were conducted in the open air, the workmen selecting their positions with reference to the direction of the wind. Thus no injurious effects, nor even inconvenience, were experienced by those employed.

(13) c. *Treatment of the Cotton with the mixed Acids.*—About twelve hours before immersion in the acids, the skeins to be operated upon at one time

(which had previously been dried in the air) were suspended in a capacious and well-ventilated drying-chamber, the temperature of which was maintained, for the above period, at not less than 49° C. They were then transferred, while in the chamber, to stoneware jars with tightly closing lids (the same as were used for keeping the cotton immersed in acid), and were allowed to become perfectly cold in these before submission to treatment with acid.

The vessels which were found most suitable for use in treating the cotton with the acid were large and rather deep stoneware pans: one, provided with an iron lid, contained the quantity of mixed acids required for the treatment of a certain number of skeins; a second, which was fitted with a perforated ledge of iron, and was surrounded by cold water, served for the treatment of the cotton, which was conducted as follows:—a proportion of the acid having been transferred to the second pan, two skeins were thoroughly immersed in it, and stirred about for two or three minutes; when saturated with acid they were raised upon the shelf and pressed together with the paddle, so as to allow the superfluous acid to flow off; the quantity of acid absorbed by these skeins was replaced in the pan by an addition of fresh acid, and further skeins were immersed, those which had drained being transferred to a jar while the freshly immersed ones were soaking. In this way the operation of immersion was continued until the whole of the skeins to be treated at one time had been transferred to the jars, six of the large yarn or nine of the fine being introduced into one of these.

The skeins were pressed down in the jars by means of the paddle, and sufficient acid was added just to cover the cotton completely. The jars were then closed and placed into vessels containing water, in a cool building, where they remained for forty-eight hours.

It was found an important precaution to keep the vessel in which the cotton was first immersed surrounded with water, especially in the warm season during which these experiments have been conducted, as the evolution of heat during the first action of the acids upon the cotton is considerable. The contents of the jars to which the gun-cotton was transferred were not found to become heated to any important extent, even when not surrounded by water. The proportion of acid to cotton said to be contained in the jars, as the process is carried out at Hirtenberg, is that of ten to one; but it was found necessary, in order to cover the cotton completely as directed, to employ at least fifteen parts of acid to one of cotton. This proportion would doubtless be much diminished if means were employed for compressing the cotton in the jars more highly than was the case in these experiments.

The precaution of adding a fresh supply of the acids to that which remains in the immersing-vessel after the withdrawal of each quantity of cotton treated, was proved by experiment to be of the greatest importance in securing the uniformity of the product. In one of the first operations, no fresh quantity of acid was added before immersing the skeins treated last. In other respects these skeins were submitted to precisely the same treatment as the remainder (*i. e.* an additional quantity of acid was added to them in the jar, they were allowed to remain for forty-eight hours, &c.). When examined synthetically, they furnished at least one-half per cent. more cotton than the skeins first treated in the same operation; and when fired in the proof-mortar, a decidedly lower range was obtained with the cotton last treated.

(14) d. *Purification of the Gun-cotton.*—At the expiration of forty-eight hours the jars were conveyed to a centrifugal machine, by which the principal quantity of acid was separated from the cotton. The machine employed at Hirtenberg for this purpose is made of copper, the one used by me was constructed entirely of iron, the sides of the revolving cylinder consisting of coarse iron-wire gauze, rendered sufficiently rigid by an iron framework. After each operation the machine was washed out with an abundant supply of water, and thus the corrosive action of the acids upon it has really been very trifling. The oxide dissolved by the acid when the skeins were placed in the machine was sufficient to colour the liquid, and also to stain the cotton in places, but these stains disappeared entirely in the first washing which the product received. The skeins were rapidly transferred, by means of an iron hook, to the machine, and the latter was then set in motion, at first slowly, and ultimately at a speed of 800 revolutions per minute. Within ten minutes the acid was so far separated from the cotton that the skeins were only damp.

Some precautions were necessary in effecting the first transfer to water of the skeins, with acid still clinging to them. If they were simply thrown into water so that the latter would penetrate them only gradually, the heat resulting from the union of the free acids and the water immediately established a violent action of the nitric acid upon the cotton, quantities of nitrous vapours being disengaged. At Hirtenberg the gun-cotton, when taken from the machine, is quickly placed under a small cascade, where its saturation with water is effected with very great rapidity. As this arrangement was not attainable at Waltham Abbey, the skeins, directly they were removed from the machine, were plunged singly, as rapidly as possible, and moved about violently, in a large body of water. They were then washed by hand in a stream until no acid taste whatever was perceptible in the cotton, and were afterwards immersed in the stream for a period of not less than forty-eight hours. For this purpose they were arranged in rows upon poles fixed in frames, which were so placed in the water that the skeins were in a vertical position, the water circulating among them freely. The current of the stream used at Waltham Abbey (at the only available place for these experiments) was not so rapid as could have been desired, and the dryness of the season had rendered it unusually sluggish; still it was sufficient to afford a continual change of the water surrounding the cotton. The character of this water is by no means such as to render it specially fitted for the purification of the gun-cotton. The bed of the stream is always thickly covered with luxuriant vegetable growth, and the water itself is consequently so highly charged with vegetable matter, that, although light was excluded as far as possible from the cotton during its immersion, the skeins became covered in many places, within a few days, by vegetable growth, which in time attached itself so firmly to the cotton as to be very difficult of removal by hand-washing.

The system of purification, as carried on at Hirtenberg, differs very considerably from that described in General Lenk's process as patented in this country. At the above-named establishment, the gun-cotton is in the first instance left in the stream for three weeks and upwards; it is afterwards washed in a dilute solution of carbonate of potassa, again washed in water, dried, and then treated with a solution of soluble glass. After this treatment it is dried, washed for six hours in the stream, and finally by hand.

In the patented process, it is directed that the gun-cotton in the first instance should be immersed in running water for *forty-eight* hours and upwards; it is not submitted to any treatment with carbonate of potassa, but is boiled, after the first washing, in a weak solution of soluble glass, and on its removal from this, without any intermediate desiccation, it is immersed in the stream for about six days.

The process of purification which I adopted differed from that in use at Hirtenberg only in the postponement of the long-continued washing until after treatment of the gun-cotton with alkali. At the expiration of forty-eight hours the skeins were removed from the stream, the water was separated from them in the centrifugal machine, and they were then boiled for a few minutes in a solution of carbonate of potassa of spec. grav. 1·02. Having been returned to the centrifugal machine, for the separation of the alkaline liquor, they were again placed in the washing-frames and left in the stream for a period of fourteen to eighteen days. On subsequent removal from the stream, each skein was washed by hand, to separate mechanical impurities, and one-half of each quantity of gun-cotton prepared was finally left in soak in distilled water for some hours. I found that, in consequence of the very large quantity of salts of lime in the river-water, the proportion of mineral matter in the gun-cotton was notably increased (it varied from 1 to 1·5 per cent.); this final washing was consequently adopted (there being a good supply of distilled water at hand) for the purpose of reducing the proportion of mineral matter added to the gun-cotton by the long-continued immersion in the stream. The gun-cotton thus finally purified was dried in the open air.

(15) e. *The treatment of the purified Gun-Cotton with Soluble Glass,* which forms one of the features of the Austrian system of manufacture, was stated by the officials at Hirtenberg to effect two important objects,—first, a retardation of the combustion of the gun-cotton; and secondly, its protection from atmospheric influences, by the formation of a coating upon the fibres of the cotton. In my account of the results of examination of the specimens of Austrian gun-cotton, I have entered fully into the reasons and facts which lead me to the conclusion that the treatment with soluble glass, the subsequent desiccation, and the final washing of the gun-cotton for five or six hours do not practically exert any effect upon the properties of the material, the only result being the addition to the mineral constituents of a small proportion of silicate of lime.

In General Lenk's process, as described in the English patent, the soluble glass is applied, as already stated, to the gun-cotton which, after the removal from the acids, has undergone no further treatment than an immersion in running water for forty-eight hours or thereabouts; when removed from the bath of silicate, the gun-cotton is not dried, but at once immersed for a period of six days in running water. It is at once obvious that this treatment cannot exert any effect upon the cotton, beyond possibly the neutralization of a minute trace of free acid still retained by it after the first washing. That the treatment with soluble glass is not intended to exert any other than a purifying effect upon the gun-cotton, appears also to have been understood by Professors Redtenbacher, Schrötter, and Schneider, in their inquiry into Baron Lenk's system of manufacture; for the only allusion which in their joint report they make to this point, is as follows, "the treatment with soluble glass has no influence on Baron Lenk's gun-cotton, it being previously free from acids."

In order to test, as nearly as possible in its integrity, the system of manufacture as carried on at Hirtenberg, it was determined to submit one-half of each quantity of gun-cotton produced in one operation to the treatment with soluble glass, the other half being dried, as a finished product, after the immersion in distilled water above-mentioned.

The purified skeins to be treated with silicate of soda were first exposed to air until moderately dry, and then soaked for one hour in a boiling solution of the silicate, containing ten per cent. of that substance. When the excess of the liquid had been subsequently removed by means of the centrifugal machine, the gun-cotton still retained about 80 per cent. of the solution, which, by evaporation, left therefore about 8 per cent. of soluble glass in the material. The skeins were thoroughly dried in air, and then immersed in the stream for about forty-eight hours. A longer period of immersion was adopted than in use at Hirtenberg, on account of the comparatively sluggish current of the river. The skeins were finally washed by hand and dried, this operation completing the manufacture of the gun-cotton. A comparative examination of the ash of a " silicated " product with that of gun-cotton prepared at the same time, which had not undergone this treatment, exhibited a difference amounting to about one-fourth of the ash existing in the gun-cotton not treated: the latter furnished 1·45 per cent., the silicated left 1·85 per cent. of ash. The proportion of silica left in the gun-cotton was decidedly greater than that found in the Austrian specimens; but the portion not treated with soluble glass also contained a very notable amount of silica, derived from suspended matter in the water. A portion of gun-cotton treated with soluble glass has been washed for a few hours only, for comparative experiment.

(16) Artificial heat was not employed in drying any portion of the purified gun-cotton. This operation was accomplished by suspending the skeins during the day upon lines in the open air, or in a well-ventilated shed in wet weather and at night.

Miscellaneous Memoranda.

(17) 1. Samples of the products of manufacture obtained at Waltham Abbey have been submitted to synthetical examination, and furnished results as uniform as could have been anticipated, and corresponding to those demanded by the formula

$$C_{36}\left\{\begin{matrix}H_{21}\\ 9NO_4\end{matrix}\right\}O_{30}.$$

In the course of the manufacture the increase of weight actually sustained by the cotton has been directly determined, and it has been found that 100 lbs. of cotton, purified by the treatment with alkali, furnished about 177 pounds of gun-cotton (not silicated). The amount which theoretically 100 lbs. of cotton should furnish, of gun-cotton of the above composition, is 183·3 lbs. The discrepancy between these numbers is certainly not great when allowance is made for mechanical loss in the various washings, and for the foreign matters dissolved out of the cotton by the acids.

(18) 2. Several experiments have been instituted for the purpose of examining the characters of the product resulting from the treatment of cotton with the mixed acids which have already been used once. The quantities of cotton treated at one time, and the various steps in the manufacture, did not differ in any way from those adopted in the regular system in use. The product obtained from the coarse yarn, by means of the once-used acid, has been examined synthetically, and found to correspond very nearly in composition to gun-cotton of the formula

$$C_{36}\left\{\begin{matrix}H_{22}\\ 8NO_4\end{matrix}\right\}O_{30},$$

or the next lowest substitution-product to that obtained in the ordinary process of manufacture. It was found, moreover, that the cotton yarn obtained in this experiment was very decidedly weaker (*i. e.* could sustain only considerably less strain) than the ordinary product—a result which must be ascribed to the greater predominance of sulphuric acid in the mixture which has been once used.

Experiments with this mixture and the *finer* yarn, furnished a different result to the foregoing. The products corresponded closely in composition to the theoretical result attained by the original or first employment of the acids. The rotting or weakening effect noticed above was much less apparent in these products than in the case of coarse yarn.

It would appear from these results that the mechanical condition of the cotton (*i. e.* the thickness of the yarn) exerts an important influence upon the nature of the product furnished by the once-used acid. Further operations are in progress in which this acid is employed; and the explosive effects of the resulting products will be carefully compared with those of the material obtained in the ordinary way.

(19) 3. No systematic artillery experiments or others illustrative of the explosive effects of gun-cotton prepared at Waltham Abbey have as yet been instituted, beyond a few trials of small charges in the mortar employed at the Gunpowder Works for purposes of proof. Even these results, however, as far as they go, are possessed of considerable interest, as demonstrating some of the most important points of difference between gun-cotton and gunpowder, when used in cannon, and as illustrating to some extent the value of the simple mechanical means devised by Baron Lenk for regulating the explosive action of the gun-cotton.

A quantity of the coarse roving, corresponding in weight to one-third of the proof-charge of gunpowder, was wound round a conical wooden plug, with the application only of a slight strain (equal to two ounces). The range obtained by this charge, or cartridge, was fully equal to that furnished by a full-proof charge of Enfield-rifle powder. The same weight of gun-cotton, wound upon a cone of the same dimensions, but kept during the winding under a strain of one pound, gave a range which was materially shorter than that furnished by the loosely wound charge, but quite equal to the average proof range (or three times the weight) of ordinary cannon-powder. Results agreeing with the above, and in very good accordance with each other, were obtained in frequent repetitions of those experiments.

The variation in composition of exceptional or special products, such as have been referred to in the preceding, manifested themselves in a corresponding variation in the range obtained with them, when tried under the same conditions as the ordinary products. Thus the skeins which in one particular operation had, as above described, been immersed finally, without addition of fresh acid, and which furnished synthetically a somewhat high proportion of cotton, did not yield so long a range as the ordinary products, nor as the first skeins obtained in the same operation. Again, the coarse yarn which had been treated with acid already once used, when wound into cartridges with a strain of two ounces on the yarn, did not furnish as long ranges as the ordinary products wound under a strain of one pound; and when made into cartridges under the latter conditions, the ranges it furnished were very considerably below the average results obtained with the ordinary product.

The absence of any appreciable residue in the mortar, and of any but the most trifling amount of smoke, only noticeable if watched for, were, it is hardly necessary to say, novel and important features in these few proof experiments.

(20) 4. Some observations made during the drying, and in the preservation

in store, of the finished gun-cotton, can hardly be passed over altogether without notice in this communication, though the precise nature and cause of the result which has manifested itself are still undetermined.

By far the larger proportion of the gun-cotton prepared at Waltham Abbey was dried in the open air, being exposed to strong daylight, and very frequently to powerful sunlight. When dry, it was packed into ammunition-boxes—large wooden cases containing an internal casing of tinned copper and with very tightly closing double lids. In opening some of these boxes containing gun-cotton, a faint but peculiar odour was accidentally observed, which was more distinct in some boxes than others. This observation led to the introduction of some pieces of litmus-paper among the skeins in different boxes, and these were found in some instances to change, after the lapse of time, to rose-colour, some merely at the edges, others more or less perfectly throughout. The change of colour was like that produced by carbonic acid upon litmus; and if the boxes were left open for some time, the paper gradually regained its original colour. If they were again closed for twenty-four hours or longer, the reaction upon the litmus-paper was again observed in those instances in which it had first been decidedly manifest, but it has been noticed to become gradually weaker. It was subsequently found that the gun-cotton, after it had been for some time exposed to strong daylight, and particularly to sunlight, in the open air, exhibited the same slight acidity, and that the reaction noticed in the boxes was always more marked in those which contained the gun-cotton most recently exposed for drying.

As above stated, no satisfactory explanation can as yet be afforded of the occasional exhibition of this slight acidity in the thoroughly purified gun-cotton under the circumstances described; to whatever causes it may be due, it appears evident, on a perusal of the report of Drs. Redtenbacher, Schrötter, and Schneider upon Baron Lenk's gun-cotton, that those chemists have noticed a similar occasional acidity as occurring in the Hirtenberg cotton, and, indeed, that this acidity has been dwelt upon as a cause for alarm by persons who have feared the spontaneous decomposition of the gun-cotton. The surmises as to its possible origin, put forward in the report above referred to, are, it must be confessed, not very satisfactory; neither, in the face of the extraordinary precautions adopted for effecting the complete purification of the gun-cotton, is the force of the following concluding paragraph of that part of the report which refers to this subject, very apparent:—"These acid traces should the less evoke surprise when we bear in mind that the gun-cotton in process of manufacture had been exposed for forty-eight hours to a strong acid bath; moreover, if the subject of comparison, viz. gunpowder, be tested with equal severity, similar evidence of chemical action will be forthcoming." It is in a material in which, in the first instance, the most delicate tests fail to detect the slightest evidence of free acid, that this slight acidity occasionally becomes evident. That exposure to light will, after some time, induce decomposition in the most carefully purified gun-cotton, is beyond dispute: as the latest of many proofs, which I myself have had of this, I may mention that some litmus-paper which has been for a few weeks exposed to light in a stoppered glass bottle, together with a piece of the Hirtenberg cotton, has become already perfectly bleached. But that an indication of change, such as has been dwelt upon above, should be afforded by so brief an exposure to light as five or six hours, and continue to be afforded after the cotton has been removed from light, appears to me to favour one of the conjectures put forward in the report referred to,—namely, that the gun-cotton may contain traces of high nitro-compounds which are much more liable to decomposition than it is itself

—a conjecture which may receive some support from the fact of the cotton being exposed for a very long period to the action of the acids. Under any circumstances, this is a matter which may be most intimately connected with the question of the keeping qualities of the gun-cotton, and which therefore requires the strictest investigation.

(21) 5. While referring to the question of the stability of gun-cotton, it may be important to record the following fact. It is pretty generally known that, soon after the discovery of gun-cotton by Schönbein in 1846, Messrs. Hall and Son, the extensive gunpowder-manufacturers at Faversham, entered upon the manufacture of this material, but were, after a time, so unfortunate as to have a very disastrous explosion of gun-cotton at their works, which, after a careful inquiry, was ascribed, by the jury and by all connected with the manufacture, to the spontaneous combustion of the material. The manufacture was stopped on the occurrence of this accident, and a considerable quantity of gun-cotton, which existed in the works, was buried by Messrs. Hall's direction (in July 1847), being simply thrown into a hole in the ground and covered up with earth. At my request, Messrs. Hall have been so kind as to have a sample of this gun-cotton, which has been buried for sixteen years, dug up and forwarded to me. This cotton, after being freed from dirt by washing, presented a discoloured appearance, and is stained in many places with oxide of iron, but it exhibits not the slightest evidence of having undergone change. The fibre is perfect throughout, and there is, as might have been anticipated, no trace of acidity manifest in any portion. It is not a rapidly burning gun-cotton, and leaves, upon ignition, a considerable carbonaceous residue; it does not therefore consist, or at any rate not entirely, of the most explosive substitution-product. A specimen, purified in the first instance by treatment with dilute hydrochloric acid, has been examined synthetically, and yielded 59·63 per cent. of cotton,—a result which agrees most closely to that which would be furnished by a product of the composition $C_{36}\left\{\begin{matrix}H_{23}\\ 7NO_{4}\end{matrix}\right\}O_{30}$ (which would furnish 60·66 per cent. of cotton). Messrs. Hall manufactured the gun-cotton by Schönbein's original process, which consisted, as far as I can learn, in the treatment of the cotton for about one hour with a mixture of one part of nitric acid of spec. grav. 1·45 to 1·5, and three parts of sulphuric acid of 1·85 spec. grav. The cotton was washed in running water until no acid was detected by litmus-paper, and afterwards dipped in a very weak solution of carbonate of potassa. The finished cotton was sometimes soaked in a weak solution of nitrate of potassa.

The examination of Messrs. Hall's buried gun-cotton appears to afford an interesting and important proof of the permanence of gun-cotton when excluded from air and light, but not protected from moisture—though it is necessary to bear in mind that this particular material does not correspond in composition to the regular Austrian product.

(22) 6. Referring once more, in conclusion, to the manufacturing experiments which form the main subject of this communication, it only remains to be stated that the very high price paid for the cotton for these experiments, the necessarily temporary arrangements, and the impossibility of fully economizing labour and material in carrying out the manufacture with such accommodation as could be furnished without any important outlay at Waltham Abbey, rendered the formation of any reliable estimate regarding the cost of the gun-cotton out of the question. But the scale upon which the manufacture was conducted has been quite sufficient to demonstrate most satisfactorily that, with a properly organized system of operation, the production of the gun-

cotton is certainly not more difficult or complicated, and is attended with considerably less risk of accident to the workmen and the manufacturing establishment, than the production of gunpowder.

IV.—*Information given by* Baron Lenk *on June 22 and July 14*, 1863.

1. *What weight of gun-cotton and gunpowder give equal effects?*—In accordance with experience, gun-cotton produces the same effect as three times its weight of gunpowder, which proportion, under certain circumstances, may be increased to six times its weight of gunpowder; for the effect of gun-cotton in proportion to gunpowder is the greater the more resistance is offered to the charge by the sides which enclose it, *and the less gas can escape at the beginning of the explosion.*

2. *What bulks of each give equal effect?*—The space required for a gun-cotton cartridge, to produce an equal effect, is scarcely half as large as that of a gunpowder cartridge; and it is only made equally large or slightly larger, if secondary circumstances should demand it.

3. *Is the effect more constant with gun-cotton or with gunpowder.*—The effect of small fire-arms and of artillery in general is considerably more uniform and constant with the use of gun-cotton than with gunpowder, provided the proper charge and cartridge has been taken.

That superiority gun-cotton partly owes to the chemical process by which I have produced it, and partly to the uniform formation of the cartridge, which can only be attained by its regular texture, using it in the shape of cotton-yarn.

4. *Which admits of more precise aim?*—On account of the more constant effect of gun-cotton, and because its use prevents fouling of the gun, which further admits to reduce the space between shot and barrel, and on account of less heating of the gun, as well as by the uniform position of the cartridge, there must be a more precise aim of shot with gun-cotton—which, moreover, has been fully proved by experience.

5. *Which occasions least recoil?*—Chiefly on account of the smaller space of time the projectile requires to pass through the barrel of a gun to attain a certain initial velocity, the recoil of the gun is less than with the use of gunpowder. It may be stated that, by the official trials of the Commissioners in the year 1860, the recoil of the gun with gun-cotton was found to be 0·68 of that with gunpowder.

6. *What is the relative effect as to fouling?*—Except an extremely small residuum of carbon, there is no deposit with the use of gun-cotton. The barrel of a gun requires no cleaning out; there is no chemical effect upon cast- and wrought-iron, steel, or bronze barrels by using gun-cotton cartridges.

7. *Is gun-cotton liable to decay when stored?*—Gun-cotton has been stored like gunpowder for twelve years, usually packed in wooden boxes; and no trace of alteration has been discovered. My own experiments go back as far as 1846, and have given most favourable results in this respect.

8. *How is it affected by water or damp?*—Gun-cotton placed under water is unalterable. By the transformation of ordinary cotton into gun-cotton, it loses the greater part of its hygroscopic property, so that gun-cotton, properly manufactured, resists the influence of damp much better than gunpowder; and moreover it cannot, like gunpowder, get permanently spoiled thereby. Gun-cotton, if dried in the open air, contains 2 per cent. moisture; ordinary cotton about 6 per cent. Gun-cotton, placed in a room completely saturated with

moisture, after thirty-three days of exposure contained 8 per cent. moisture, whilst under the same circumstances gunpowder was saturated with 79·9 per cent. of water; some weeks afterwards the whole saltpetre of the gunpowder was converted into a concentrated solution of saltpetre, whilst gun-cotton took no more than 8 per cent. of water as a maximum saturation.

9. *Which admits of most rapid firing?*—The gun being heated considerably less by using cotton-cartridges, the absence of a noteworthy residuum and smoke admits of a more easy manipulation and sighting of the gun, and thereby secures a more continuous and rapid fire.

It may be stated that 100 rounds with gun-cotton were fired in thirty-four minutes, and the barrel was heated to fifty degrees Cent.; whilst 100 rounds with gunpowder-cartridge in 100 minutes heated the gun so much that water dropped on the barrel immediately evaporated with noise, though three times as much time was required with the powder charges. The Commissioners continued the trials with gun-cotton up to 180 rounds without any danger from heating being apprehended, whilst the Commissioners thought it advisable, for the sake of safety, not to continue firing with powder charges under the above circumstances.

10. *What effect has gun-cotton on the coolness and cleanness of the gun?*—It has been already mentioned that, with the use of gun-cotton, fire-arms remain considerably cooler than with gunpowder; and the slight residuum has no influence upon the effect of the gun.

11. *How far is it adapted for breech-loading.*—There being no fouling of the gun, it follows that with the use of breech-loaders the construction of the breech may be kept quite tight.

12. *How is it for precision of aim?*—Under all circumstances the aim is not disturbed or interrupted, there being no smoke attending the discharge of the gun.

13. *Has it any special advantages in forts, ships, and casemates?*—From many experiments, but especially from the official trials made in the casemates of the fortress of Comorn in the year 1853, it results that under circumstances which would render the firing with powder difficult or even impossible, there was no trouble or molestation in any way to those serving the guns with the use of gun-cotton cartridges.

The trials in the fortress of Comorn were made in casemates, ventilation being intentionally obviated. After fifteen rounds with powder cartridges, further sighting of the gun was impossible; after forty-six rounds, one of the men serving the gun fell into convulsions of suffocation; a second man being ordered in the place of the first disabled man, got immediately sick on entering the casemate; the rest of the men were more or less stupefied; it was necessary to stop firing after fifty rounds given in eighty minutes. By using gun-cotton cartridges, on the contrary, after fifty rounds the men serving the gun felt not the least molestation, and the aim was always clearly visible.

14. *How is it adapted for mining?*—The more accelerated effect of gun-cotton, and the possibility of enclosing in the same space more than double the quantity of gases, especially direct us to employ gun-cotton where it is desired to attain an energetic effect for mining-purposes, for example, to secure harbours by means of sea-mines.

15. *What is the relative danger of manufacture?*—In the manufacture of gun-cotton every manipulation, up to its final accomplishment, is without any danger whatever, whilst with the manufacture of gunpowder danger of explosion exists from the beginning of the operation.

16. *What is the comparative risk in conveyance?*—The smaller weight of gun-cotton, as well as the smaller volume of it for an equal effect, favours the conveyance of gun-cotton considerably; and it may be taken moreover into consideration that the dangerous "getting to dust" of powder cannot take place with gun-cotton.

The transport of gun-cotton to the most distant parts of the empire of Austria under intentionally difficult circumstances, has always been effected without difficulty.

17. *How is it adapted for shells?*—Shells filled with gun-cotton hold a considerably larger quantity of material for the production of gases; at the same time, it is in the nature of both compounds that gun-cotton developes far quicker the gases of combustion than gunpowder; for this reason, shells filled with gun-cotton burst into at least double the number of pieces.

18. *Is it liable to spontaneous explosion?*—From the last Report, dated June 1863, of the Professors of Chemistry appointed by the Minister for War to report on that subject, and to give their opinion, and which is submitted to you, the apprehension of self-explosion has in no way any foundation whatever.

Without direct ignition, gun-cotton may detonate between iron and iron if a heavy blow be struck; but it is known that only that part explodes which was hit, without communicating ignition to the surrounding particles. If, however, even with an iron hammer, gun-cotton be struck a heavy blow upon bronze or other soft metals, or upon stone, no detonation can take place. In every report of the Austrian Empire Commissioners, that subject was considered and disposed of as not impairing the safety of manipulation.

19. *How far is it possible to regulate its explosive power?*—It has been established by experience that it is possible to moderate the force of gun-cotton within very extensive limits, and thereby to suit it to the different purposes without having ground for apprehension that variable effects would be the consequence; that valuable property of gun-cotton, however, requires that the trials be made under the superintendence of an expert, which will secure the desired effects to a certainty.

20. *What is its cost of manufacture?*—Supposing quantities which would produce equal effects, then its cost is considerably less than that of gunpowder; under ordinary circumstances and normal prices of cotton, the cost of manufacture of gun-cotton is under fourteen pence per pound, but at the present high price of raw cotton its cost will be under twenty pence per pound weight*.

21. *Give us what in your opinion are the essential points in the manufacture of gun-cotton.*

a. *Cotton.*—Any sort of cotton may be used for the production of gun-cotton, provided it be tolerably free from seed-capsules and oleaginous matter. Absence of the latter is indeed imperative; hence factory cotton, as ordinarily obtained, must be digested in a weak alkaline solution, as is usual in such cases.

Other forms of lignine can be substituted for cotton to produce an explosive material—viz. flax, hemp, bog-grass, maize, straw, rags, sawdust, &c. I have given rules so as to meet the case of either of these; however, it is only in some extraordinary cases that any of these materials are to be preferred to cotton; further, ulterior applications of the explosive material are much facilitated by the device of *spinning* into threads.

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* Baron Lenk subsequently reduced this estimate.

b. *Nitric acid.*—The nitric acid employed must be in the highest possible degree of concentration; and here the remark should be made, that an impurity of hyponitric acid imparted to the acid by concentration, and which is difficult to eliminate, does not prejudice the acid for this special application.

c. *Sulphuric acid.*—The ordinary commercial sulphuric acid of spec. grav. 1·84 answers perfectly.

d. *Mixture of the acids.*—This consists of *one part by weight of nitric acid, and three parts (weight) sulphuric acid,*—assuming the nitric acid employed to possess an average specific gravity of 1·485. If, however, the specific gravity should differ from the above, then cognizance of the amount of anhydrous acid supplies the data necessary for regulating the mixture.

The mixture is effected by means of an apparatus represented by fig. 1.* The vessel C is filled with the predetermined quantity (equivalent to the required weight) of nitric acid; B and D with sulphuric acid. This being done, the acids from the three vessels are allowed to run very slowly into F, in which is an agitator T, set in motion by the handle L. As soon as a portion of the two acids has been mingled in this manner, the mixture is allowed to run from F to G, and the operation resumed as before.

The reservoir G being completely filled, its contents must be set aside in closed vessels. It is advantageous to preserve the mixed acids a considerable time in the above vessels; in no case must the mixture be used until it has become quite cold.

e. *Process of steeping.*—Cotton-wool ordinarily absorbs about 6 per cent. of atmospheric moisture, which must be dissipated in a drying-room heated to 95° F. previous to dipping the cotton.

Steeping is effected in an apparatus represented by figs. 2, 2*a*, and 2*b*. The apparatus, during the process, is kept *cool* by a constant change of cold water poured into the vessel F. The chamber A contains a store of acid, B sixty pounds of the acid mixture, D represents the vessel in which the cotton is stored after dipping is accomplished. Two skeins (about 3 ounces) of dried cotton are dipped at one operation in the mixture contained in B, the spatula G being used to effect, by pressure, complete incorporation between acid and cotton; in the next place, the cotton is to be removed from the bath, laid upon the rack C, and pressed to such extent that the amount of mixed acids left absorbed by the cotton be in the ratio of 10½ *lbs. of the former to* 1 *lb. of the latter.* The cotton being now lifted into the vessel D, this is to be filled with mixed acids, and the portion of acid absorbed made good by means of the tared spoon E, in such manner that the surface in B may always maintain the same level for every additional portion of cotton dipped.

The vessel D filled in the manner prescribed, is at length set aside, the due proportion of its contents being regulated, if necessary: the regulation is easily accomplished after a little practice, but it is seldom requisite. The cotton is next compressed by the handle H in such manner that it is wholly covered by acid, to the further action of which it is left exposed for the space of forty-eight hours; it must be cooled during that exposure, thus guarding against the violent action of the acids resulting in decomposition.

f. *Removal of acid from the gun-cotton.*—This is performed by means of a centrifugal machine, the drum of which is of copper, a material which lasts a considerable time; after this manipulation, there still remain 3 lbs. of acid in the gun-cotton manufactured from 1 lb. of ordinary cotton. This must be got rid of by rapid water affusion applied in some convenient manner.

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* This refers to a drawing exhibited at the time.

Mere affusion, however, does not suffice to get rid of all the adherent acid, hence the cotton must remain for a yet *longer* period in a stream of water, natural or artificial.

g. *Impregnation of gun-cotton with soluble glass.*—The object of this process is to close the pores of the gun-cotton fibre by silica precipitated within them, by which the velocity of explosion of gun-cotton is hereafter retarded; moreover any lingering traces of acid that may remain are neutralized by combination with soda liberated from the soluble glass. This operation is performed by means of a centrifugal machine, into which a central tube passes for supplying the glass solution. By this arrangement the liquid is driven in very minute division through the gun-cotton; the glass solution employed has a density of 12° Baumé. The material having been treated as described, has next to be dried by atmospheric exposure: as drying proceeds, decomposition of the soluble glass goes on. Atmospheric carbonic acid uniting with soda, forms carbonate of soda, whilst silica is precipitated.

The carbonate of soda thus produced being soluble in water, can be got rid of hereafter by washing, whereas the precipitated silicic acid not being soluble, remains attached to the cotton fibres, protecting them from decomposition under atmospheric influences, however high the temperature may be.

h. *Treatment with soap.*—For many purposes it is desirable to retain the fibres of gun-cotton soft, in order to guard against the contingency of explosion from very violent friction, gun-cotton being somewhat harsh to the touch.

This is readily effected by dipping the material, already treated with soluble glass and washed, previous to final drying, into a soap ley, the excess of which is to be hereafter squeezed out, and the gun-cotton finally dried.

22. *Have you any special information to give the Committee respecting the practical applications of gun-cotton?*

a. *In general.*—The proper utilization of gun-cotton presupposes a thorough knowledge of the nature of its energy and the bearing of its mechanical advantages, in order that the object proposed may be gained through a favourable choice of circumstances. These influences are more perceptible with gun-cotton than with gunpowder, inasmuch as gun-cotton admits of variation from a point of *inefficiency* to one of *highest energy.*

Ignited in an open space (*i. e.* not under pressure), the explosive effect of gun-cotton is trifling, very much less than that of gunpowder. Ignited in spaces more or less closed, then in proportion as the closure is perfect does the explosion assimilate itself to that of gunpowder, the force of which under certain circumstances it considerably surpasses; *i. e.* it is dependent on the resistance met with. The maximum of the explosive effect of gun-cotton is attained when the charge is so regulated, as to dimensions and form, that the whole of it becomes ignited before the yielding of any side of a vessel in which it is enclosed.

The products of combustion of gun-cotton are wholly gaseous, whereas gunpowder by combustion yields only 31 per cent. of gas, whence it would seem that the energy of a charge of gunpowder should be nearly equalled by a charge of gun-cotton only one-third of its weight. The available power of one part of gun-cotton by weight, may, under certain circumstances, be raised to the effect of six parts by weight of gunpowder.

b. *Application of gun-cotton as a charge for smooth-bore guns.*—The standard of reference was furnished by experiments conducted with a twelve-pounder bronze field piece, which gave results as follows:—

The weight of shot, solid round, used was 12 lbs.
Diameter of shot 4·5 inches. (English weight and measure.)
Diameter of bore for gun-cotton 4·56 inches.
Diameter of bore for gunpowder 4·67 inches.

Result.	Gun.		Cartridges.		Initial velocity.	General Observations.
	No.	Length of Bore.	Material of Charge.	Length.		
I.		13½ calibres.	Powder 3 lbs. 1 oz.	7·5 in.	1400 ft.	Normal.
II.	2	11½ ,,	Gun-cotton. 13·6 oz.	5·1	1375	Cartridges slightly compressed, filling the whole space.
III.	,,	11½ ,,	,, 14·8	,,	1407	
IV.	3	10½ ,,	,, 13·6	,,	1358	
V.	1	11½ ,,	,, 14·8	8·3	1400	Hollow cartridges represented at Plate II. fig. 2.
VI.	1	10 ,,	,, 15·9	,,	1426	
VII.	1	9 ,,	,, 17·0	,,	1402	

The normal performance of ordinary powder-guns gives result I., as compared with gun-cotton. With gun-cotton, when compressed charges were used, each of 13·6 oz., result II., gun 2; the gun was not injured; while with 14·8 oz. of charge, after a few rounds, a considerable enlargement of the bore, where the shot lies, took place. A similar result happened to a second gun, No. 3, even with a charge of 13·6 oz., after the first few shots.

When one of the enlarged cartridges, represented at Pl. II., fig. 2, was used, occupying 1·1 of the powder-space, the gun's endurance was perfect, and no loss of effect was sustained, and its practice remained good, as proved by results set forth at III. and V., since *equal charges* in *very different spaces* (*i. e.* in the ratio of 5 to 8) still produced equal results.

In proportion as the tube is shorter, an increased charge is required (shown by results V., VI., VII.); yet the effect of a normal powder-gun and charge may be attained by a tube shortened from 13½ to 9 calibres: it follows that guns to be used with gun-cotton may be constructed much shorter than if intended to be charged with gunpowder*.

With the largest charge used, *i. e.* 17 ounces, about 1000 shots were fired from the same gun, without affecting the piece in the slightest—an endurance very satisfactory, and considerably greater than has been experienced with gunpowder.

This experiment was further continued for arriving at results by empirical means as to the strength of metal in various parts of the tube.

The original tube, formed as depicted at Pl. I. fig. 2, was gradually turned off until it assumed the shape figured in broken lines, but without any disadvantageous effect. The metallic strength of 3·7 inches close behind the seat of the ball, where, according to experience, the greatest strain takes place, and 1″·6 at the muzzle, were so moderate that for practical uses no further diminution was desirable; hence the experiments in this respect were discontinued.

Finally, I turned my attention to the object of flattening the trajectory of projectiles with this gun, and succeeded to such an extent that a projectile fired from the gun horizontally pointed at targets set up at 100 yards from each other as far as 1200 yards struck at an *even height* at 3 feet from the ground, and fell *without ricochet* at about 3200 yards.

An experiment made with a Krupp cast-steel 6-pounder, demonstrated that with harder and more resisting metal than bronze, the great power of gun-cotton might unhesitatingly be made use of to obtain a more energetic projectile force than would have been compatible with the use of gunpowder.

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* No details are given as to precision.

The results are as follows:—

A Krupp 6-pounder, cast steel, charged with 30 oz. of normal powder	1338 feet per second initial velocity of shot.
A Krupp 6-pounder, cast steel, charged with $13\frac{1}{2}$ oz. of gun-cotton	1563 feet per second initial velocity of shot.

In practice it is necessary with the use of gun-cotton to reduce the "windage" to a minimum; otherwise larger charges must be used, and with no corresponding advantage.

c. *Application of gun-cotton to rifled ordnance.*—The time may have arrived for breech-loaders, which have lately come into use under such good auspices, to be set aside in favour of muzzle-loaders, for the service of which gun-cotton offers such facilities, because of its leaving no solid residue after combustion, and because windage admits of reduction to a minimum.

The method of determining the condition of charge differs from the data given for smooth bores, in so far that the vehemence of explosion may be decreased by mechanical means—such as variation of length of chamber, regulating the mode of ignition so as to attain a sufficiently favourable condition of starting of the projectile from rest. This result was easily achieved (as demonstrated by experiments conducted in Austria) within the degrees of velocity hitherto deemed sufficient, as by the gun shown, Pl. I. fig. 1, and cartridges, Pl. II. fig. 1.

To what extent these deductions may hold good at higher velocities, must be determined by further experiments, which may be expected, judging from present data, to give favourable results.

The Austrian breech-loading guns (cast iron) of three service calibres (6, 12, and 24-pounders charged with 13, 30, and 60 lbs. weight projectiles respectively) answer perfectly when charged with gun-cotton, provided the chambers are enlarged to 1·1 of the original capacity for powder. For larger charges, cartridges made in the form of a hollow rope, similar to those used for blasting, would answer; however, I have to remark that it is more necessary in rifled than in smooth-bore guns to reduce the windage to a minimum; this, on account of the surprising exactness of work in English factories, would be easy of accomplishment, and would raise the effect of gun-cotton. Experiments performed with a cast-steel gun of 3 inches diameter, weighing only 50 lbs., firing hollow projectiles with effect to 3000 yards, demonstrate that, on account of the short length of tube necessary and the slight recoil, very light pieces can be made, Pl. I. fig. 3; the carriage was about 40 lbs. weight.

d. *Application of gun-cotton to small arms.*—In this respect it is important to observe that the plasters used with the old round-ball rifles were completely torn so long as short cartridges were used. When I elongated the cartridges the plasters resisted perfectly, and practice was very accurate; hence it is demonstrated that *length* is a very important element in the construction of small-arm cartridges. Experiment only can determine the *proper* length.

One circumstance is not to be lost sight of—that with a *very* long cartridge the *ignition* of it in proper time may be difficult to achieve. Practice in the application of mechanical means is requisite to secure the proper explosion of long cartridges by igniting them *well* in front. Lastly, experience proves that in small-arm cartridges *separation* of the cotton into several layers, by the interposition of paper, influences the result. Small-arm cartridges which have answered best are composed of three layers of flat woven gun-cotton with paper interposed. For the small-bore long range rifles used in England, the cartridges most suitable may be those represented at Pl. II. fig. 3, the precise dimensions of them being fixed experimentally. On the 4th and 5th of July 1863, there was a preliminary trial at Manchester, during which it was found that no distortion of the projectiles ensued even when the proper conditions of charge were departed from by using too heavy charges.

e. *Application of gun-cotton to purposes of mining.*—Gun-cotton is more appropriate to this use than gunpowder, which it surpasses in proportion as the mass to be blasted is more compact. Assuming a solid rock to be blasted, and that the proper condition of charge together with the proper distribution of holes have both been heeded, the relative proportions of gun-cotton and of gunpowder for producing an equal effect are 1 gun-cotton to 6·274 gunpowder (weight by weight), whilst the relative proportions for wall-blasting (masonry) are 1 gun-cotton to 2·25 gunpowder; however, here the point must be noted, that when these experiments were performed the *best shape* of charge had not been determined. According to experiments more recently conducted, the form of charge for blasting which best answers is that of a *hollow twisted rope*, according to sample; the operation of charging is rendered thus very easy and safe—wooden tamping-rods being used until the charge is covered. According to repeated experiments, the strongest friction of gun-cotton between stone is unattended with the slightest danger. For large charges, it is to be remembered that *complete* ignition is more difficult than the complete ignition of large powder charges; to accomplish this result satisfactorily for mining-purposes, it is indispensable to fasten up the gun-cotton in *tightly closed vessels*—which afford the necessary resistance, *not yielding until the whole mass of gun-cotton has become ignited.* Experiments have proved that little barrels with strong hoops answer best. The proper construction of these restraining cases can be learned experimentally from models, when it will be remarked that *no smoke* results from explosion, and *very little fire* is seen.

As a charge for hollow projectiles, gun-cotton substituted for gunpowder will produce similar effects; but then the space of shell is only *partly* filled, even when the bursting powder charge is raised to its maximum. An increased charge of gun-cotton may be employed with advantage, which thus, in comparison with gunpowder, will give an additional effect, partly referable to additional material used, and partly to the occurrence of a more rapid explosion.

With projectiles having very small holes for filling, the accompanying samples were used, because of the ease with which filling could be conducted. When projectiles with cylindrical bore, capable of being thrown open, have to be filled, it would be advisable to insert cylindrical charges of gun-cotton previously compressed. A soft layer of felt is recommended to be laid interiorly against the base of the projectile—though this precaution does not seem to be imperative, no premature bursting having taken place in the course of any experiments.

f. *Application to fuse-purposes.*—For fuses gun-cotton is woven (according to pattern given), then steeped in saltpetre and covered with a jacket of india-rubber. In this manner the progress of combustion is rapid (over 30 feet per second); the line will bear considerable pressure, and may even be folded crossways without fear of the fire leaping from one fold to the other.

If ordinary gun-cotton thread be fired in a train loosely, ignition is very slow, about 1 foot per second.

V.—*Extracts from a Report on* Baron LENK'S *Gun-cotton, by* Professors Dr. REDTENBACHER, Dr. SCHRÖTTER, *and* Dr. SCHNEIDER, *to* His Excellency Field-Marshal JOHANN FREIHERR KEMPEN VON FICHTENSTAMM, *President of the Royal Imperial Commission on Gun-cotton, June* 1863.

(1) "*Difference between the French Gun-Cotton and* Baron Lenk's.—According to the method pursued by the French Commission, the raw cotton was immersed in the acid mixture for one hour. Baron Lenk leaves his cotton forty-eight hours in the acid bath. The French cotton was afterwards dipped in running water for an hour or an hour and a half. Baron Lenk's gun-cotton lies four, six, or eight weeks in a stream. The French cotton had, after washing, so much free acid left, that wood-ash lye (a solution of carbonate of potash, therefore) was neutralized by contact with it, and after long use became sour. Baron Lenk's cotton is so freed from acid by long immersion, that a two per cent. solution of potash, in which two cwt. of gun-cotton had been boiled, has lost none of its alkaline properties—that is to say, that the cotton was completely free from acids, as experiments wholly accordant with those of the Imperial (Austrian) Engineers' Committee fully demonstrated. The French gun-cotton having been prepared in a manner so different, it must necessarily have had a different composition to that of Baron Lenk's; hence it is clear that the French experimental results cannot, without considerable reserve, be accepted as precedents."

(2) "*Analysis of Austrian Gun-cotton. Laboratory of Engineers' Committee,* 1861.

In 100 parts.	Trinitro-cellulose, calculated.	No. 4.
Carbon	24·3	25·1
Hydrogen	2·3	3·0

University Laboratory, 1863.

In 100 parts.	No. 3. 1856.		No. 6. 1860.		No. 14. 1862.			Dinitro-cellulose, calculated.
	1.	2.	1.	2.	1.	2.	3.	
Carbon	24·4	24·5	24·6	24·2	23·6	23·9	24·1	28·6
Hydrogen	2·7	2·8	2·6	2·7	2·6	2·4	2·4	3·2

"If this analysis differs somewhat from the theoretical formula of the trinitro-cellulose, the circumstance must be remembered that cotton is not pure cellulose, but that it consists of long-extended vegetable cellules, in which there is always a little albuminous substance containing over 50 per cent. carbon, and 7 per cent. hydrogen, the presence of which even in such quantities easily increases the percentage of carbon and hydrogen. The treatment with soluble glass has no influence on Baron Lenk's gun-cotton, it being previously free from acids. Gun-cotton is always put into comparison as an explosive compound with gunpowder; but it must be remembered that one of the component parts of gunpowder (charcoal) is most irregular in quality, especially where the primitive method of preparing it is followed. Still, in theoretical disquisitions upon gunpowder, charcoal is taken into account as pure carbon."

(3) "In the magazines of gun-cotton at the Neustadter Haide, there are stores of various years. In the laboratory of the University there are samples of Hirtenberg gun-cotton of three several years, which have been examined by the above named artillery officers, and they have been found not to differ materially in their composition from trinitro-cellulose. For instance—

In 100 parts.	Trinitro-cellulose, calculated.	No. 3. 1856.		No. 6. 1860.		No. 14. 1862.		1862.
		1.	2.	1.	2.	1.	2.	3.
Carbon ……	24·3	24·4	24·5	24·6	24·2	23·6	23·9	24·1
Hydrogen ….	2·3	2·7	2·8	2·6	2·7	2·6	2·4	2·4

"If these results are compared with each other, there can be no right to say that Hirtenberg gun-cotton alters by keeping. They agree as far with each other as analyses of the same material usually do. It is to be regretted, on this as on many other accounts, that during the last twelve years such analyses were not frequently repeated. If the opponents of gun-cotton, in performing an adverse experiment, heat the substance in a test-tube up to 100° C., and holding litmus-paper over it, deduce from redness of the latter that gun-cotton changes after long keeping, they merely prove thereby that gun-cotton changes at 100° C. Of an explosive compound, it can only be required that *it shall not deteriorate within certain limits of temperature,—a requisition amply fulfilled by Lenk's gun-cotton.*

"Some varieties of gun-cotton, if enclosed together with litmus-paper in a tube, often manifest an acid reaction at ordinary temperature. This may arise from various causes. There may exist, for example, free acids. These acids may be the result of nitrogen partially oxidized, and may result from imperfectly worked cotton. This assumption granted, the phenomenon is explained, and the cause easily avoided. It may arise from decomposition of the gun-cotton, atmospheric dampness having brought about a partial reconstitution of the cellulose."

(4) "But some specimens of Lenk's cotton do not even yield traces of decomposition. A parcel of Hirtenberg cotton was laid for six weeks in a pond, and not subsequently treated with potash. It was then deposited in a running stream, afterwards exposed for one month to the air, being subjected to all the various influences of dew, rain, and sun, day and night continuously. It retains all its original explosive qualities, and fails to redden litmus-paper, even though the latter be wrapped in a mass of this cotton and allowed to remain for many days. The results of an analysis of this cotton were almost identical with the calculated elements of trinitro-cellulose, as the following Table makes apparent:—

	Calculated.	Found.
Carbon …………………	24·2 ……..	24·4
Hydrogen …………….	2·3 ……..	2·8

(5) "*Temperature at which Gun-cotton ignites.*—The rejection of gun-cotton, in consequence of the changeable nature, or explosive quality of the material at low temperatures, is so thoroughly and decidedly contradicted in the Re-

port of Baron von Ebner, that it would be superfluous to go any further into this question—the lowest explosive temperature of the Hirtenberg gun-cotton being therein fixed at 136° C., a temperature which, practically, cannot raise any doubts against the use of gun-cotton."

(6) "*Experimental proofs demonstrate that Lenk's Gun-cotton is not spontaneously combustible.*—The history of gun-cotton, as chronicled by chemists and artillerists, short though the history be, is so full of records of explosion under unexpected circumstances, that an unbiased mind can hardly fail to be impressed with the belief that, amongst the ordinary conditions of military practice, there may be some competent to induce the spontaneous combustion of this material. Nevertheless the experience of Baron Lenk, acquired during a period extending over more than ten years, is more pregnant with reliable testimony than can be found in the entire remaining history of this material.

"*The manufacture of gun-cotton in Hirtenberg consists of a number of perfectly harmless operations*; and it is remarkable that, contrary to what happens with gunpowder, if fire be not actually applied, explosion is impossible. All operations are so arranged that the material acted upon is in a moist or wet condition—hence not explosive. Drying takes place in a capacious building, on every side open to the air. The last process of drying is carried out in the drying-chamber, where it is effected by a stove situated on the outside, distributing its heat to the building by earthenware pipes—drying being thus ensured through a gentle warmth. The gun-cotton next goes either into a magazine to be packed away in chests, or is at once prepared for ammunition. In this magazine, Hirtenberg cotton has been stored for a period of twelve years, and not a single instance of explosion has taken place. How many powder-mills have exploded in that time? In Prussia, however, a drying-chamber has lately blown up. Your Excellency has officially been informed, that in Prussia they have worked for eight years with gun-cotton, and not a single explosion has occurred except the last-named. In the Prussian drying-chamber referred to, a stove with iron smoke-pipe was used—a sufficient explanation of the misfortune.

"During twelve years we have prepared gun-cotton at Hirtenberg for ammunition—that is, for yarns, spun ropes, and threads twisted and woven. One single case of explosion has occurred in the course of Baron Lenk's manufacture, the result of improper speed of working the spinning machinery. Now, the circumstance hardly need be insisted on, that gunpowder as well as gun-cotton can be exploded by friction. Gun-cotton has been used for military purposes now more than twelve years; it has also been employed for mining and blasting. It has been subjected to every variety of transport. Packed in black wooden chests, it has been exposed to sunshine for months together—all this without one single accident. In the face of such testimony, it cannot be said that gun-cotton manifests any tendency to explode spontaneously."

(7) "Lieutenant von Karolyi's analysis of the gases of combustion of Lenk's gun-cotton, which he made in the Chemical Laboratory of the Engineers' Corps Committee, may be seen in the 'Report of the Imperial Academy of Science,' vol. xlvii. Mathematical and Physical Part, p. 59, and is given in the following Table, in which the gases of combustion of powder according to Bunsen (*vide* Poggendorff, 4th series, vol. xii. p. 131) are cited in comparison with those of gun-cotton.

Gases of Combustion. Volume per cent.	Bunsen.	Karolyi.		
	Sporting powder.	Rifle powder.	Ordnance powder.	Gun-cotton.
Nitrogen N	41·1	35·3	37·6	12·7
Carbonic acid CO_2...	52·7	48·9	42·7	20·8
Carbonic oxide CO ...	3·9	5·2	10·2	29·0
Hydrogen H.....	1·2	6·9	5·9	3·2
Sulphuretted hydrogen HS ...	0·6	0·67	0·86	Carbon 1·8
Oxygen O.....	0·52	—	—	Water 25·37
Light carburetted hydrogen ..	—	3·02	2·7	7·2

"If we compare the gases of gunpowder with those of gun-cotton, we easily see that the chemical action of the product of combustion of gun-cotton on the sides of the barrel, if there exists any action at all, must be smaller than with the use of gunpowder, because they are less oxidizing gases than those of gunpowder. Should, therefore, bronze barrels be "burnt out" by the use of gun-cotton, cast steel may be then used instead of bronze, which, in fact, has been successfully done. Moreover bronze gun-barrels have withstood a sufficient number of rounds by using an adequate charge of gun-cotton with elongated cartridges. In this way no alteration of the bore prejudicial to the correctness of aim has taken place. From the steel barrel of a rifle, forty rounds have been fired with gun-cotton cartridges, which have hit the target 300 yards distant in an unexceptionable manner. After the said number of rounds, the barrel was internally as clean and polished as a mirror. It appears, then, that this problem is solved in a general and satisfactory manner."

(8) "*Application of Gun-cotton to Mining Warfare.*—Gun-cotton is also used for mining-purposes and mining warfare. On this subject nothing but what is favourable has been reported by the Imperial Engineers (*vide* Communications of the R. I. Engineers' Committee, 1861, vol. i., by Moritz Baron von Ebner, Colonel of the Engineers). However, it is said that the gases of gun-cotton were more poisonous in mines than those of gunpowder, and therefore the use of gun-cotton for mining warfare is not to be recommended. If we compare the result of Lieutenant Karolyi's analysis of the combustion-gases of gun-cotton with those of gunpowder as above given, we observe that both of them contain irrespirable gases; further, that they contain qualitatively the same sort of irrespirable gases; and although the relative quantities of some of the gases from powder and gun-cotton are different, the effect of those gases leads to the same practical result, viz. that, after blowing up a mine, one cannot without danger approach the spot of the explosion before renewing the air by ventilation. In this respect, we may say that the gases of gun-cotton will be more quickly removed by ventilation than those of gunpowder, because the first-named contain a greater quantity of gases easily dissipated, since 100 pounds of gunpowder contains 68 pounds of fixed solid matter, which alone suffices to make respiration almost impossible. It is not probable that an explosive compound will be found which will produce any other but irrespirable gases. It is one and the same in practice, whether a cellar contains 40 per cent. of carbonic acid and 10 per cent. carbonic oxide, or 30 per cent. carbonic oxide and 20 per cent. carbonic acid, inasmuch as no one could, without danger of suffocation, enter such a cellar. Both the gases of gun-cotton and of gunpowder, according to Karolyi, may be ignited by a match."

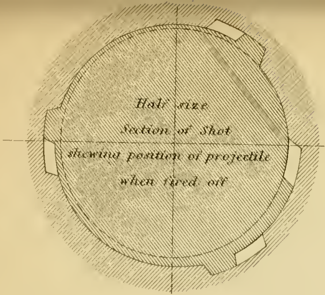


Fig. 1. ($\frac{1}{12}$ full size)

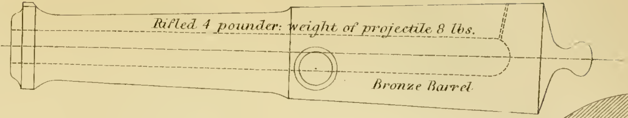
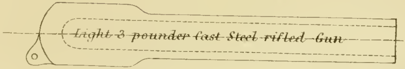


Fig. 3. ($\frac{1}{12}$ full size)



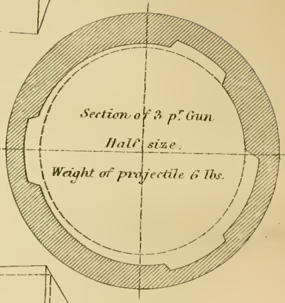
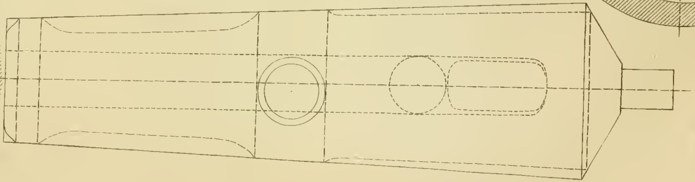
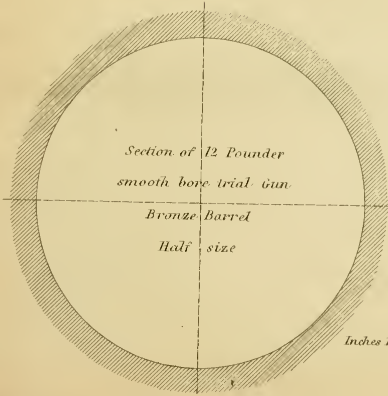


Fig. 2. ($\frac{1}{12}$ full size)





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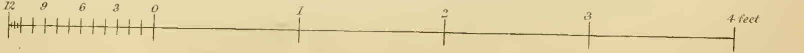


J.W. Lowry fc.

Fig. 1.

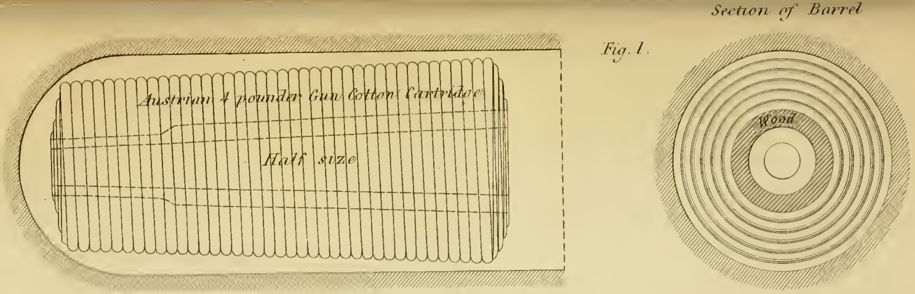
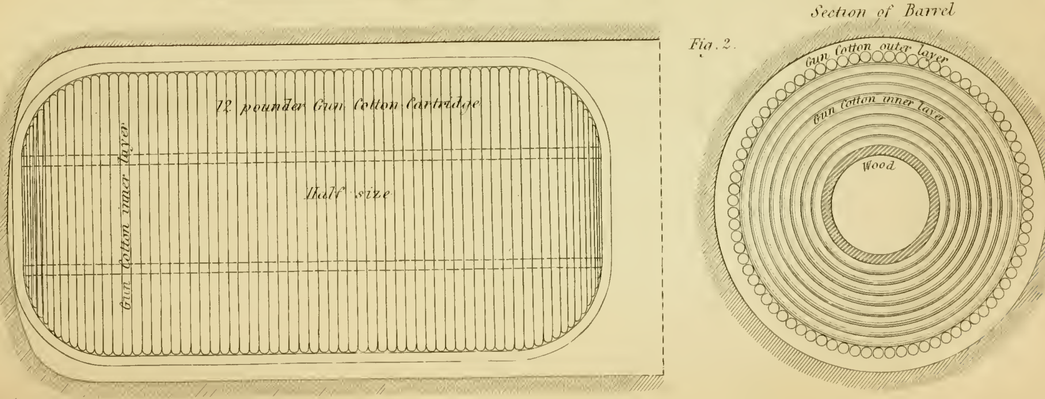


Fig. 2.



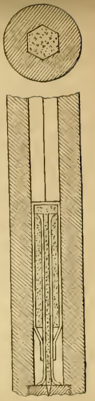


Fig. 3

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